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for educators in the fields of engineering and allied sciences



SUSPENSION PROGRESS

Why A Technical Education?

RECENT events in this International Geophysical Year have given dramatic emphasis to the entire field of science and technology. Scientific advances as reported by the government, by educational institutions, and by industry are now the object of more widespread interest than ever before.

This interest directs attention to the value of a technical education for our young people. Certainly in industry it is of value to the scientific and technical people who push ahead in unexplored fields, who develop new products, and who conduct the day-to-day technical operations that are becoming more complex and larger in number. Likewise, there are increasing numbers of business situations where technical people need to participate in decisions on policy. Good management also requires a sound understanding and a recognition of science and technology by its non-technical leaders.

In General Motors, where our business depends heavily upon engineering and manufacturing activities, we naturally have placed strong emphasis on the value of a technical education. For many years, our hiring of graduates from colleges and universities has included a large proportion of technical graduates along with graduates in other fields such as liberal arts and business administration. A broad technical and practical background also has been the basis of the training offered since 1924 at our own educational and training agency—the General Motors Institute.

This is GM's 50th Anniversary Year and in looking back over our history we see that it is liberally sprinkled with evidence of the developments by our scientists and engineers. These developments have been a major factor in our efforts to grow and to be successful in the highly competitive atmosphere of the industry in which we operate.

As we look ahead today, it is important not only to emphasize the value of a technical education, but also to emphasize the growing need for more technically trained people. This was forcefully done by President Eisenhower when he acknowledged that the trend toward Russian supremacy in both numbers and quality of scientists and engineers is "the most critical problem of all" for the American people. Later, in a report to the President by the National Committee for the Development of Scientists and Engineers, Committee Chairman Howard L. Bevis stated that "America's response to the Soviet challenge must be the marshalling of our brainpower resources, in company with the other nations of the Free World, not only for mutual defense but to meet the broader challenges of the scientific age we have entered."

Thus, it is appropriate that we in General Motors share with educational institutions, with civic agencies, and with the public, the responsibility for encouraging qualified students to seek a technical education as they prepare themselves for a place in a growing technological society. The cooperative technical

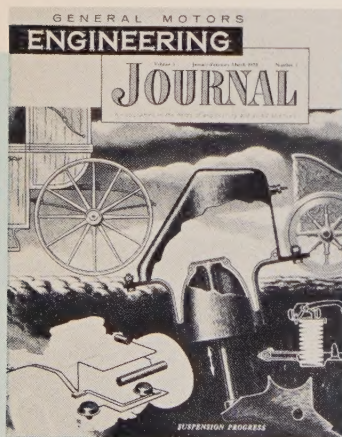


educational programs at General Motors Institute represent one effort in this direction.

Another means of encouragement is offered under the provisions of the GM Scholarship Plans. Actually, the Scholarship winners may study in whatever field they choose. It is of interest to note, however, that in the first two years of operation of these Plans, careers in the sciences or engineering represent the highest percentage—69 per cent—among those students who have indicated career choices. The next highest percentage has selected teaching careers.

In the coming age, there is every reason to believe that the pace of change will be much more rapid than during any previous period in America's technological development. The Nation will need more technically trained people to serve as able teachers to guide and stimulate others, as scientists to study the unknown, as engineers to design and develop, as technicians to build and operate, and as managers to exercise sound judgment on policy.

John F. Gordon,
Vice President and
General Executive



THE COVER

This issue's cover design—by artist John B. Tabb—is another depicting developments in transportation. It dramatizes the progress of vehicle suspension through the centuries. From the crudely suspended chariot, through the bouncy horse-drawn carriage, to today's steel sprung, smooth-riding automobile, suspension has become a highly developed art of providing passenger comfort and good

ride characteristics.

The most recent development in suspension is the air spring. Besides offering a means of maintaining a constant mean vehicle height, regardless of load, the air spring with its contribution to comfort, convenience, and safety represents a new engineering concept in the search for the ultimate in passenger car, truck, and bus transportation.

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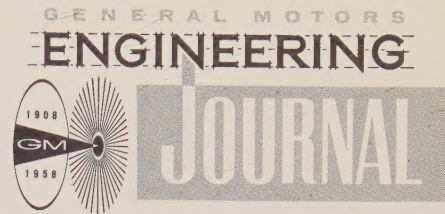
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Applying the Electrodynamic Vibrator to the Development of Military Vehicles



The effects of vibration can be very hazardous in the operation of a military vehicle. Not only do mechanical difficulties and instrument malfunctions result from excessive vibration, but the vehicle personnel are placed under an operating handicap by vibration annoyance. The control of vibration in military tanks and tank components is a problem faced by engineers at the Cleveland Ordnance Plant of the Cadillac Motor Car Division. A good method to test vibration in a vehicle is to subject it to a road test. This, however, is often prohibitively expensive. At the Cleveland Ordnance Plant, extensive vibration tests in the laboratory have been made possible by a device known as the electrodynamic vibrator. The vibrator makes possible relatively inexpensive testing, good reproduction of actual operating conditions, and easier differentiation and isolation of various kinds of vibrations. The apparatus has been used by Cadillac engineers to test tank components, and has resulted in more efficient and reliable tank equipment.

VIBRATION is uncomfortable for human beings and destructive to mechanical parts. Tanks and other track laying vehicles are relatively vigorous sources of vibration. Because of this, the effect which vibration has on components to be used in track laying vehicles is of great im-

portance to the engineer in developmental work.

In general, an item intended for use in a tracked vehicle must withstand vibration without distress, or be so mounted that it is isolated from the source of vibration. The most direct method to

Fig. 1—Requirements for military vehicles place emphasis on ruggedness and reliability under conditions which would be considered very abusive for non-military equipment. An impending shock load is pictured here as a tank negotiates a "jump" at the Cadillac Motor Car Division's Ordnance Proving Ground at West Richfield, Ohio. Continuous vibration is generated by the interaction of track blocks, road surface, and various suspension components.

test how well a mounting absorbs vibration or how well a part has been designed to withstand vibration is to mount the item on the vehicle and operate it a suitable period of time or number of miles under selected conditions, normal or severe (Fig. 1).

Vehicle testing is indisputably authentic. However, the expense and time required for testing as well as the relatively poor control of operating conditions are very serious disadvantages. It is hardly

A test method to
simulate tank vibration
in the laboratory

practical to wear out a tank in order to submit its tail lights to a 4,000-mile vibration test.

Several means of vibration reproduction or simulation, however, are available for laboratory use, thereby providing an escape from the main disadvantages of vehicle testing. Laboratory testing provides better control of test conditions, better opportunity to observe components during the test, and general freedom from the uncontrollable variables in vehicle operation, such as weather and vehicle maintenance requirements.

*Electrodynamic Vibrator
Has Gained Importance
in Vibration Testing*

One method available for simulating vibration in the laboratory is the use of the electrodynamic vibrator, which has become very important in the field of vibration testing during the past decade. Electrodynamic vibrators have replaced direct mechanical vibrators in many applications and have permitted tests to be performed which were not possible with earlier equipment.

The electrodynamic vibrator test facility (Fig. 2) may be powered by either a rotary power supply, such as a motor-generator, or by an electronic power supply. An electronic power supply greatly extends the flexibility of the system by permitting a very rapid change of frequency and/or the use of complex wave forms in vibration testing. The electronically driven electrodynamic vibrator has been used successfully in the development of several military tank components at the Cleveland, Ohio Ordnance Plant of the Cadillac Motor Car Division.

The electrodynamic vibrator is a much enlarged version of an electrodynamic

radio loud speaker without a cone. The vibrator consists of a large toroidal winding which provides a strong magnetic field in which the "voice coil" operates. This movable coil in the vibrator drives a head, or table, to which the test item is mechanically attached. The vibrator is mounted on trunnions to permit the axis of vibration to be located at any angle within a given vertical plane.

The rest of the testing facility includes a power supply which provides d-c power for the field coil and a signal section consisting of an infinitely variable audio frequency oscillator and amplifier. The oscillator provides signal voltage for an audio amplifier which powers the movable coil. The audio oscillator is equipped to provide continuously repetitive cyclic variations of the frequency within the range of the equipment. The oscillator may be replaced by a non-sinusoidal type input device, such as a magnetic tape recorder. The use of a tape recorder input permits accurate reproduction of wave forms as recorded at any desired location.

The electrodynamic vibrator test facility used at the Cleveland Ordnance Plant is designed to provide a 3,500-lb force through a continuous frequency range of from 5 to 2,000 cycles per second. When using the frequency cycling feature,

either acceleration or amplitude may be held constant, while the other quantity is varied automatically according to the requirement of physical law.

*Accurate Reproduction of
Vehicle Vibration is
Sought in the Tests*

The basic method employed in vibration simulation, as in other forms of laboratory synthesis, is to measure the phenomena in their natural habitat so that they may be reproduced as accurately as possible in the laboratory.

Measurement of vibration for laboratory reproduction or analysis is frequently done by means of a photographic oscillograph. The quantity recorded may be displacement, velocity, or acceleration versus time. It has been common practice to use displacement and/or acceleration. Displacement recordings place emphasis on the lower frequency, high amplitude vibrations. The converse is true of acceleration recordings, in which the higher frequency, smaller amplitude vibrations become more prominent.

In general, vibrations prominent in displacement recordings are those most noticeable by human beings, and are of little consequence to vehicle components. Displacement recordings in track laying

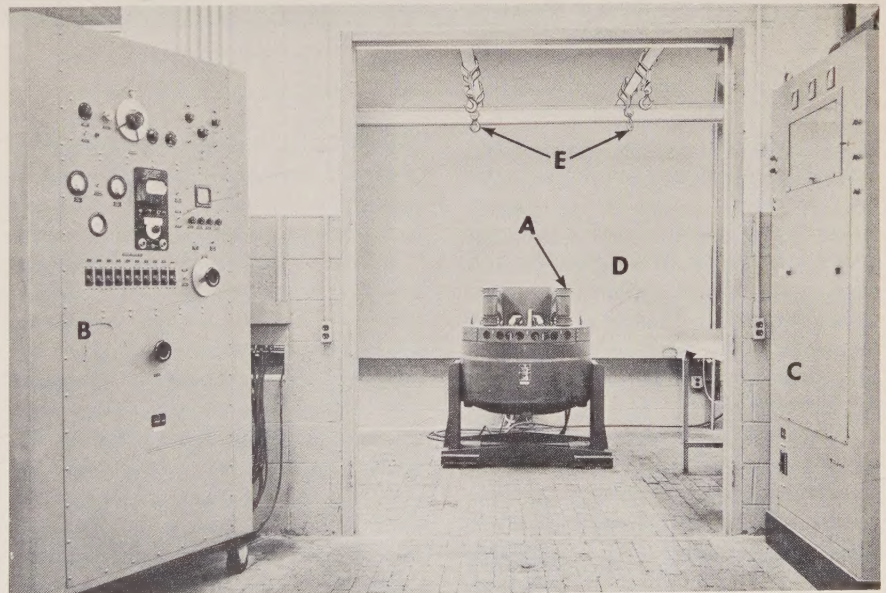
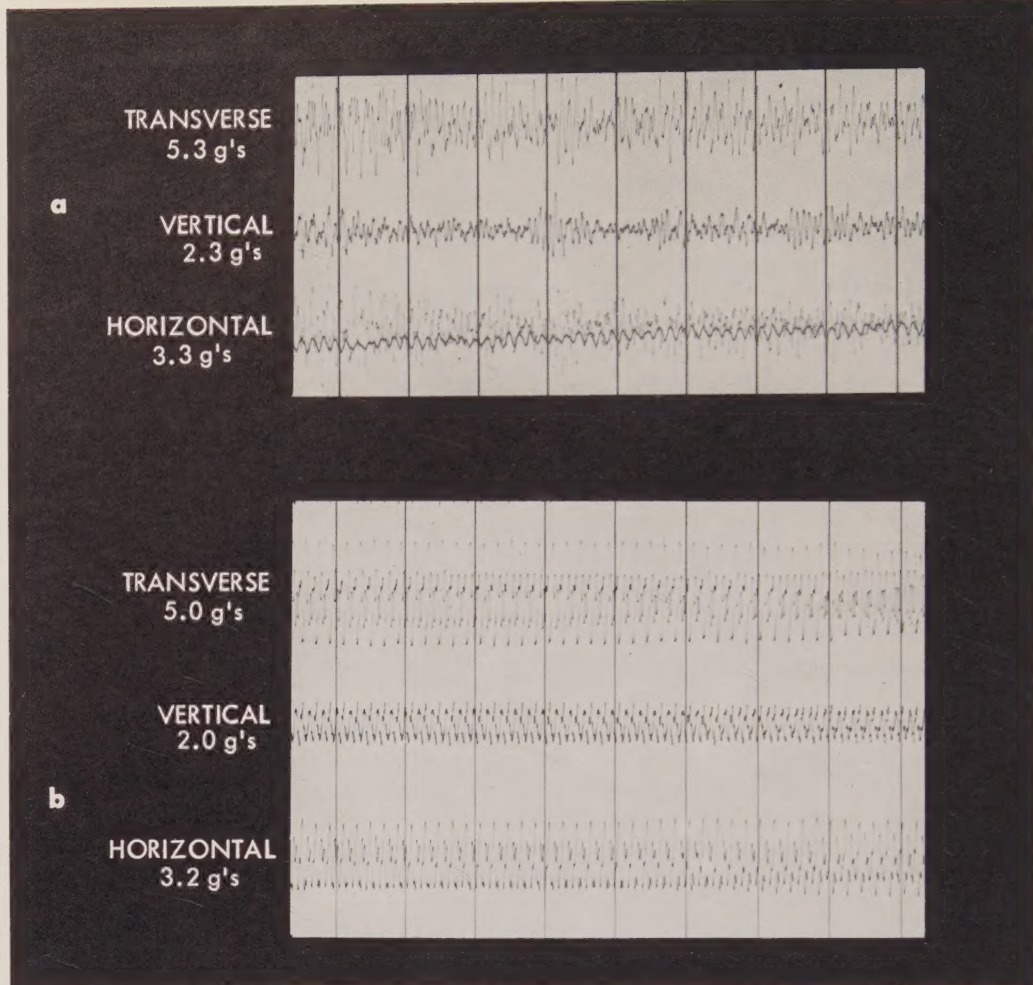


Fig. 2—The electrodynamic vibrator installation shown here is part of the vibration testing facility of the Cleveland Ordnance Plant of Cadillac Motor Car Division. The electrodynamic vibrator A is located in a separate room from the control cabinet B and electronic power supply C. The ceiling D of the room is an overhead garage door with sound absorbent material on the inside surface. The ceiling may be rolled down the rear wall of the room, as shown, to provide an overhead crane access to the vibrator. Hooks E are provided for the suspension of test samples. Associated equipment (not shown) includes blowers for cooling the vibrator and electronic console and a flexible means for driving the test objects with the vibrator head. Test objects are supported independently so that the vibrator provides only the vibrating force. Similarly, flexible drive to the test object is rigid in an axial direction only in order to prohibit the vibrator head from carrying significant side loads.

Fig. 3—An x - y plot of vibration can be obtained through the use of a photographic oscillograph and pickups. The Y axis may represent displacement (position), velocity, acceleration, or strain, while the X axis represents time. Shown above are sample portions of recordings made during vibration testing of a panoramic telescope. The upper record (a) was obtained during vehicle road operation, while the lower record (b) was made at the same location on the telescope while it was being vibrated on the electrodynamic vibrator. Each of the trace records display (from top to bottom) transverse, vertical, and longitudinal vibration of the telescope as mounted in the vehicle. The vertical lines mark off 0.1-second time intervals. The traces were recorded at the same sensitivity in terms of g 's per inch of vertical deflection of the trace. The acceleration quantity marking each trace represents the maximum acceleration measured on that trace. Good correlation exists between the two conditions in that relative acceleration amplitudes of the three axes are reproduced well and the predominant frequency repeated. The g values noted are relative to the unexcited condition in which one g vertical is continuously present. Forces acting upon the telescope and its mountings produce the measured accelerations and are in direct proportion to the accelerations according to the relationship: $\text{force} = \text{mass} \times \text{acceleration}$.



vehicle work give prominence to large amplitudes which occur in the 2 to 100 cycle per second range. The converse is again true in that the higher frequency, higher acceleration vibrations have little effect on operating personnel, but are quite destructive to mechanical items. (A human perceives mechanically destructive vibrations of 100 to 500 cycles per second frequency without serious distress.)

It is usually necessary to record the vibration at a point along three mutually perpendicular axes in order to describe accurately the motion occurring at the test point. Recordings obtained in this way usually illustrate that the wave form of the vibration is not a simple sine wave, and that predominant frequencies along the three axes are not the same (Fig. 3).

The location of vibration pickups, or transducers, is governed by several factors. In the case of component test work, recordings are often obtained for the point at which the component is mounted.

In other cases, the vibration of the component is measured. Quite often, vibration of both the mounting point and component is measured simultaneously.

A photographic oscillograph has been found most convenient for recording vibration information for tracked vehicles. The pen and ink type oscillograph lacks frequency response for the range encountered in this work. The cathode ray oscillograph has the required frequency response, but does not provide readily a large number of information channels or a convenient means of recording. From the photographic oscillograph records, information may be read or calculated on frequencies, amplitudes, forces, and accelerations. Resonant conditions, often the source of vibration excitation, may be detected from examination of these records.

Magnetic tape recordings of vibration phenomena also are very useful for both the study and reproduction of vibration

conditions. It has been customary to record displacement information (obtained from electronically integrated velocity pickups) on magnetic tapes when the recorded data is intended for use as input to the vibrator amplifier. The use of the recorded signal from the magnetic tape results in a vibrator head motion which corresponds quite closely with the motion of the point at which the vibration recording was originally made. The accuracy of vibration reproduction using magnetic tape may be verified by the comparison of photographic oscillograph records taken on the test item at the time the magnetic recording was made, and similarly obtained photographic records made on the vibrator while using the magnetic tape for signal input.

Different Transducers Increase Test Flexibility

Three types of transducers may be used to collect vibration data in connec-

tion with simulation studies. Strain gage and crystal accelerometers are used most extensively for the photographic (visible) vibration records, while velocity type transducers are used for collecting complex wave data on magnetic tape. Information useful in setting up a simulation test can be obtained with any of these three transducer types. Selection of the appropriate transducer, however, is of some benefit.

Strain gage pickups are rugged, dependable, and linear within specified limits. They are very widely used in vibration test work.

The use of crystal (barium titanate) accelerometers is generally limited to readings of test components having a low mass. These accelerometers are small and alter the test mass less than the strain gage or velocity type transducers. Disadvantages of the wider use of crystal accelerometers are: (a) characteristic low output requiring the use of a preamplifier, (b) susceptibility to noise pickup from external sources, (c) inability to record static (unchanging) acceleration, and (d) non-linearity at low frequency (below 50 cycles per second).

Mounting and Electronic Control Help Define Vibration

Vibration may be described by dimensions of frequency, amplitude, and direction of movement. These are the quantities measured in vibration testing. The accuracy with which they are reproduced is a measure of the effectiveness of the laboratory vibration test.

Unfortunately, the simplicity of this testing method is disturbed by the fact that vibration of vehicle components almost never exhibits a sinusoidal wave form, nor are the axes of vibration located conveniently. It is not uncommon for unlike frequencies to occur simultaneously along different axes in the same vibrating mass. Simulation of these relationships, however, can be obtained with very good accuracy with the electrodynamic vibrator.

Electronic control of the vibrator provides convenient control of frequency and amplitude for a pure sine wave output. Direction of excitation is obtained by an appropriate mounting of the test piece relative to the vibrator head axis. When sinusoidal excitation is used, it is possible to cycle continuously through a selected frequency range. During this cycling, either acceleration or amplitude of the

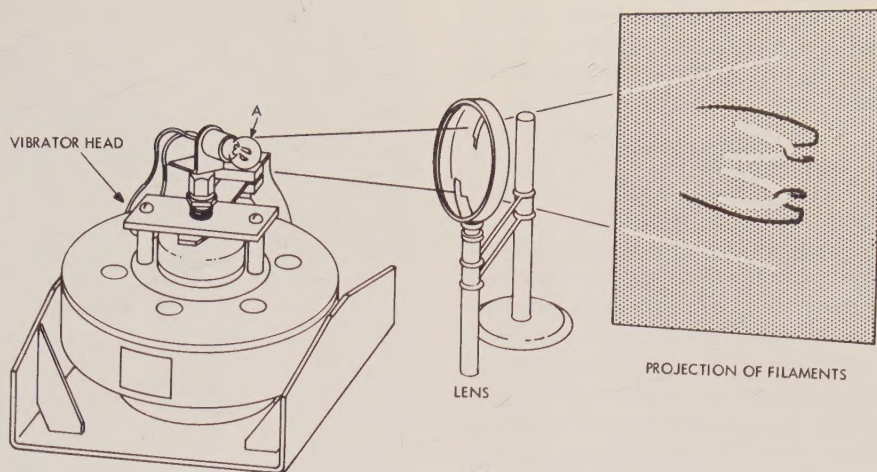


Fig. 4—This diagram illustrates a vibration test where the component being vibrated is able to be observed. A tank tail lamp bulb *A* was placed on the vibrator head. A lens projected the filament image on a screen. Before the test was run, it was suspected that the filament wire was resonating. The test, however, proved that the filament support was malfunctioning under vibration.

test piece may be held constant. More accurate reproduction of the vibration wave form encountered in vehicle operation may be obtained through the use of a magnetic tape recorder as input to the vibrator power supply.

Directional Control Aids Investigation of Resonant Vibration Distress

Directional control of the vibration exciter is exercised by appropriate mounting of the test piece relative to the vibration. Several approaches are available to the directional control. The most appropriate approach is usually apparent for a given test piece.

Resonant mounting consists simply of providing vibration excitation along the axis which is perpendicular to the plane or axis of resonant vibration occurring in the test piece. It is particularly useful in cases where distress results from a resonant phenomenon. The proper axis for resonant mounting can usually be determined from observation of the test piece on the vehicle.

After the test piece is mounted it may be monitored, particularly at the resonant frequencies, to ascertain what level of input excitation is required to duplicate the vibration severity observed in vehicle operation. The photographic oscillograph may be used for monitoring. In the case of amplitudes which are large enough to see, a strobe light tachometer

will slow the vibration to a comfortable viewing frequency.

After input amplitudes have been established which will reproduce the severity of the resonant condition observed on the vehicle, cyclic durability tests with the vibrator may proceed, utilizing the automatic cycling feature of the electrical control system.

Resultant Axis Excitation Simulates Operational Vibration

The magnitude of horizontal, transverse, and longitudinal vibration may, of course, occur in almost any relationship. These relative magnitudes may be resolved in the same manner as static forces to obtain a resultant axis, along which excitation will result in distribution of vibration amplitudes (or accelerations) equivalent to what was observed during vehicle operation. In this way, peak forces imposed on the test piece are closely approximated, even though the exact nature of the vibration movement may not be duplicated. Precise duplication of vibration conditions, if attainable, has not been warranted at the Cleveland Ordnance Plant, since the easily obtained approximate reproduction has given laboratory test results well within the realm of vehicle-to-vehicle vibration comparisons.

While the vibrator is being directed from sinusoidal or from complex wave input, it may be mechanically connected

to the test piece for either resonant or resultant axis excitation. Various possible combinations have been used in developmental work at the Cleveland Ordnance Plant.

Examples Show Use of Vibration Testing on Tank Components

An example of the value of being able to observe a component under test took place during the development of a vibration mounted tank tail lamp assembly. A tail lamp bulb was mounted on the electrodynamic vibrator and the filaments were projected on a screen for observation (Fig. 4). It was suspected that the coiled filament wire was resonating and stretching, thus allowing a portion of filament to short and burn out. When the assembly was mounted on the vibrator and excited at various frequencies, it was observed that it was not the filament, but its support, which was distorting, thus allowing the filament enough sag to short out a section. A shock mount was then developed, using a standard ordnance tail lamp housing (Fig. 5). Bulb life was increased from a few seconds to many hours.

The electrodynamic vibrator also was used to subject to excitation a component mounted in its normal environment. When chronic failures of an engine oil cooler cradle developed, Ordnance Plant engineers suspected vibration fatigue. The cradle was redesigned and then tested, using the electrodynamic vibrator (Fig. 6). Vibration direction and acceleration of the oil cooler relative to the engine were closely approximated. Comparison tests were then run between the old and newly designed oil cooler cradles. These tests indicated that the cradle redesign had been successful in that the distress was transferred to another bracket in the cooler mounting system. This bracket was then redesigned, and a satisfactory oil cooler mounting resulted.

A great amount of vibration testing time has been devoted to sighting equipment. In many cases, the optical equipment used for aiming a weapon is not shock mounted and must, therefore, be able to withstand all vibrations. This is a severe requirement for such precise, and normally delicate, equipment. In one test, two periscope heads were arranged for vibrating along their resultant axes (Fig. 7). It was observed that the

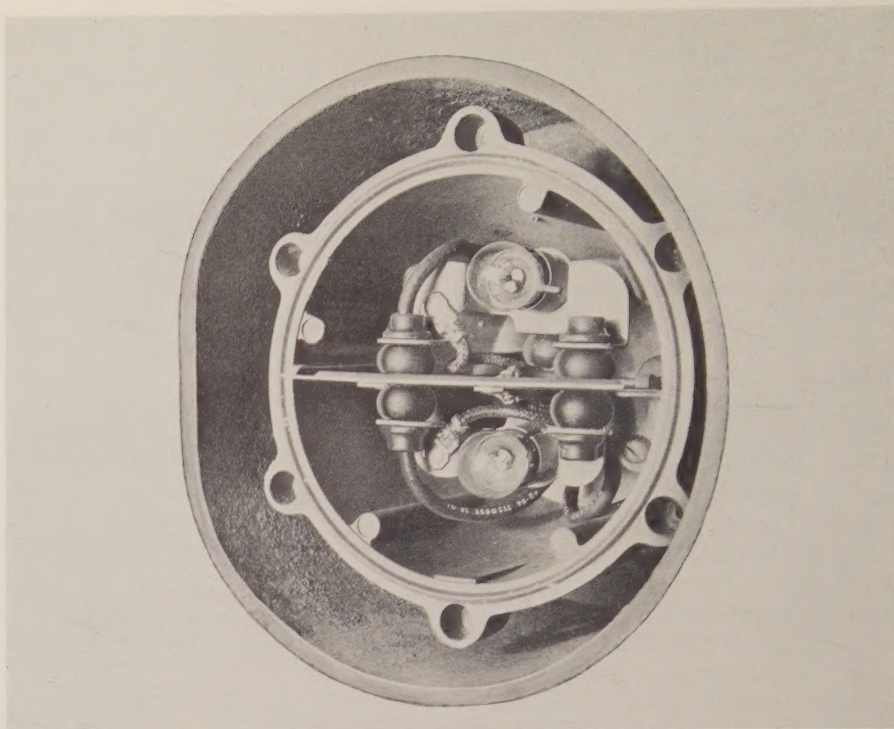


Fig. 5—In this tail lamp assembly for a tank, rubber shock mounts mechanically isolate the socket assemblies and lamp bulbs. Vibration testing provided assurance that the delicate lamp filaments would be protected from resonance.

periscope heads had a significant resonance in relation to their mounting point. This observation would have been impossible or prohibitively expensive with the periscope mounted in the vehicle during road operation. Since this resonance was not along the calculated result-

ant axis of vibration, it was necessary to alter the attitude of the periscope heads relative to the axis of excitation from the vibrator. The movement of the periscope heads, when excited on the test mount, was quite similar to the vibration observed in vehicle operation.

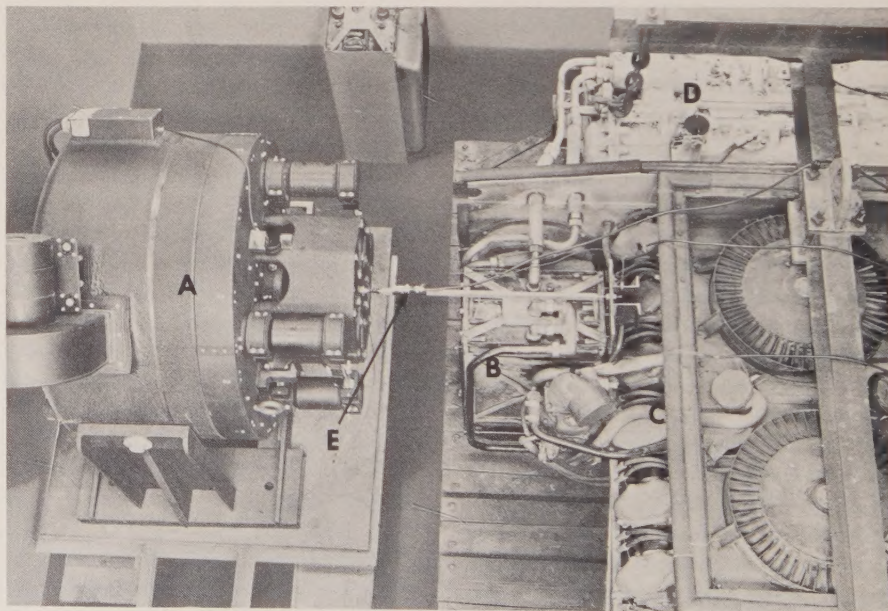


Fig. 6—Shown here is a plan view of a vibration test setup used to examine an engine oil cooler cradle mounted in its normal environment. The electrodynamic vibrator A was connected mechanically to the oil cooler B of the tank power package, consisting of the engine C and transmission D. The mechanical connector E was equipped with strain gages to permit measurement of the actual force transmitted.

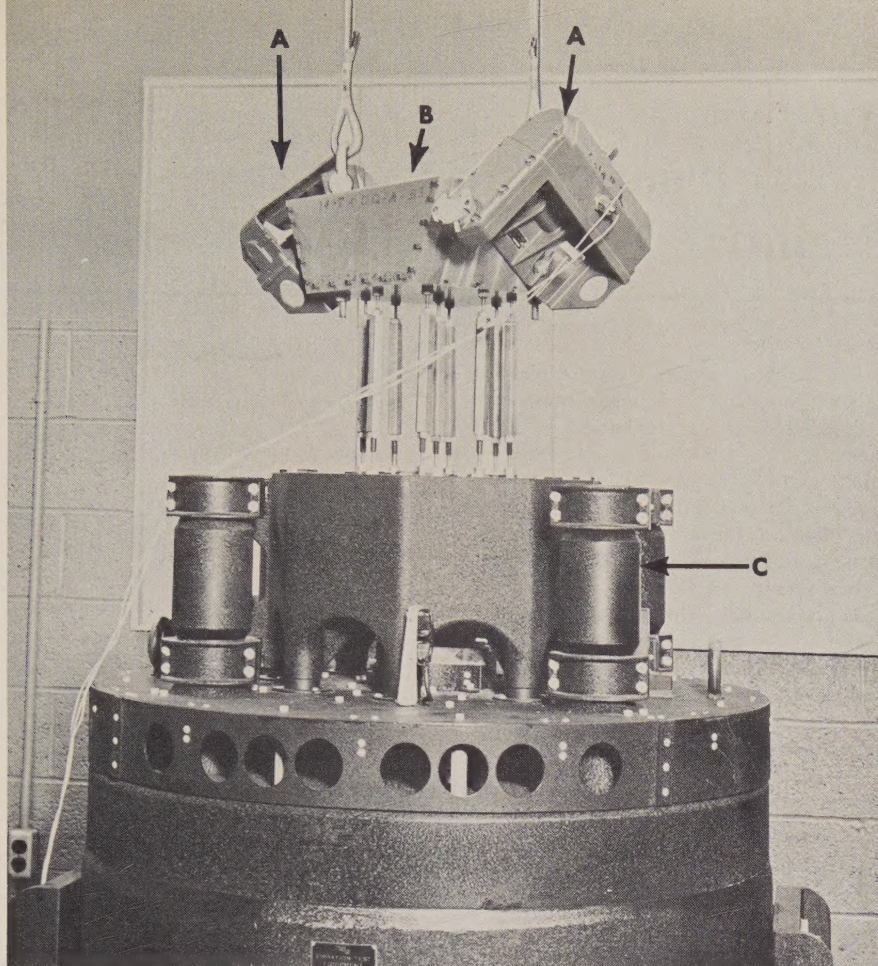


Fig. 7—Two periscope heads *A*, used in sighting equipment for a tank, were arranged for vibration along their resultant axes. The heads were mounted on the fixture *B* so that vibration excitation along a vertical axis would reproduce in the heads the same acceleration magnitude relationship present when measurements were made during vehicle operation. The large number of mechanical connections between the vibrator head *C* and the test fixture served to stiffen the fixture in the horizontal plane.

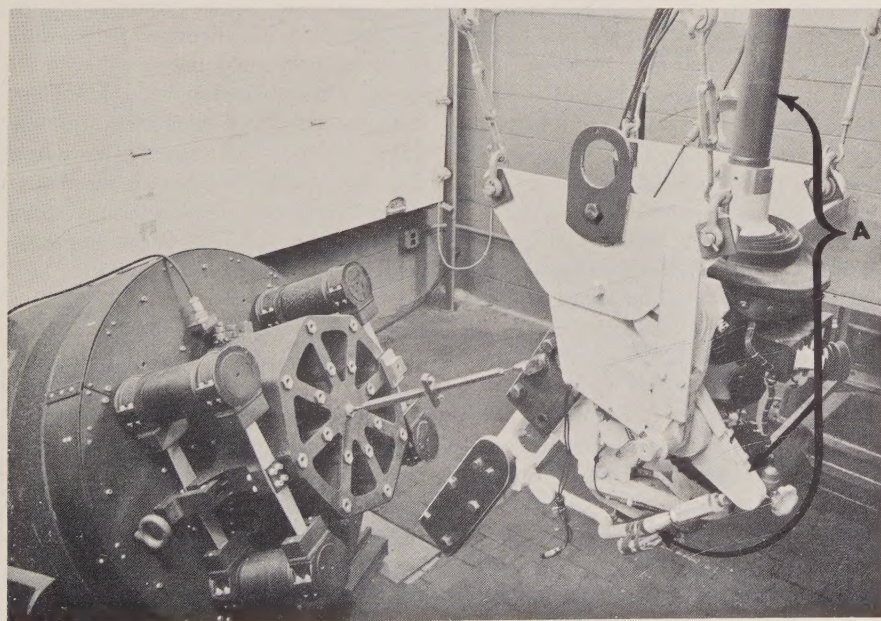


Fig. 8—The vibration test set up shown here was made to produce excitation along the resultant axis of the test object. A panoramic telescope and mount *A* were suspended in their normal attitude, with respect to gravity, and vibrated along an axis which simulated the proportions of vertical, longitudinal, and transverse accelerations previously measured in vehicle operation. The axis of excitation was carefully aligned to intersect the center of gravity of the test mass in order to minimize its rotation.

In a test run on a panoramic telescope, the test item was mounted in the same attitude with respect to gravity as its normal mounting in a vehicle (Fig. 8). To vibrate the test piece on a resultant axis, the vibrator was positioned relative to the telescope so that the projected axis of the vibrator head passed through the center of gravity of the test mass, which was composed of the panoramic telescope and mount. Vibration excitation could be introduced to the test piece along any axis desired, as long as the exciting force was directed through the center of gravity of the test mass so that wobble and bounce of the test piece were kept at a minimum.

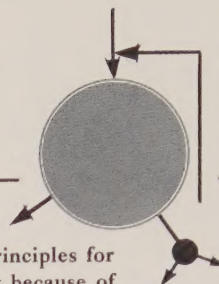
Comparative oscillographic records, which illustrated the vibration characteristics of a panoramic telescope as measured in the vehicle during road operation and on the vibrator, showed that the amplitude and frequency relationships between the horizontal, vertical, and transverse axes were closely approached on the electrodynamic vibrator (Fig. 3).

Vibration excitation using a complex wave form has been employed, using magnetic tape recorded input to the vibrator amplifier. Using an oscilloscope to compare wave shapes of the input (recorder output) and output (vibrator output), it was observed that the higher frequency components of the wave form were attenuated by the vibrator. This is not significant in track laying vehicle work, since the attenuated frequencies do not occur in important magnitudes. This type of excitation was used in a destructive test of an experimental head lamp cluster in which failures were produced on the vibrator within 10 per cent of the same operating time in which failures occurred in the vehicle.

Summary

Vibration testing has become imperative for developmental work on military vehicle components. The electrodynamic vibrator test facility has acquired the role of a fundamental tool in this work, since it has the advantages of lower cost, greater flexibility, ease of control, convenience of observation, and versatility which is limited only by the ingenuity of the user. This facility has hastened development of major items. Also, it has assisted in the "vibration proofing" of components, which could not have been justified under the costlier developmental process required by earlier methods.

Planning and Operating an Industrial Waste Disposal Plant for a New Plating Facility



By G. J. O'KANE
Ternstedt
Division

The plant discharged
clear effluent safely
and economically

Disposal systems for industrial process waste, while based on established principles for chemical and physical treatment, vary widely in their design. This is partly because of differences in the process waste being treated, and differences in the geographical location or community requirements. Disposal systems also vary because many were designed as corrective systems for undesirable conditions in an existing plant rather than as preventative systems for a new plant. An opportunity to install a preventative system was presented recently when the Columbus, Ohio, Plant of Ternstedt Division expanded its manufacturing operations and constructed a large addition adjacent to the present plant. The nature of operations at the existing plant created no difficult waste disposal problems. In the new plant, however, metal plating operations, which produce cyanide wastes, were to be installed. Thus, a waste disposal system was necessary and it could be designed concurrently with the planning of the manufacturing processes. The result was a design which produced an almost colorless, clear effluent, completely absent of any detectable cyanides, cyanates, chromic acid, or copper. The new disposal system has many automatic operations, protection against accidental discharge, and reserve capacity for future expansion, if needed.

AUTOMOTIVE hardware and trim, such as door lock mechanisms and body trim parts, are products of the Columbus, Ohio, Plant of Ternstedt Division. This plant began production in 1946. In 1955, a decision was made to expand the manufacturing operations of this plant and build a new 600,000-sq ft addition. The new addition was to accommodate plating operations and supporting fabricating equipment. These operations were not a part of the existing plant. Since metal plating produces cyanide wastes, the new waste disposal problem was considered immediately by the plant process engineers. The effluent from the plant entered the Columbus sanitary sewer system and there was no thought of discharging any waste detrimental to the sewers or to the city's biological treatment plant.

The existing waste treatment facilities of the Ternstedt Plant consisted of an independent sewer system for all industrial wastes, two parallel 77,500-gal settling and oil skimming tanks, and a means of metering the combined industrial and sanitary wastes. The small amount of cyanides present were treated with an excess of liquid sodium hypochlorite to produce an effluent containing some free chlorine. Sludge was handled by using the settling tanks alternately. About once a month accumulated sludge was pumped to a sludge lagoon with a

portable diaphragm-type sludge pump. The normal pH value of the effluent was 10 or lower. Several years earlier a water conservation program had been adopted and the discharge from the plant at that time was 15,000 to 20,000 gph.

Treatment Plant and Plating Operations Planned Together

For the job of designing the new waste disposal system, existing literature on planning disposal systems was of limited value. Most of the system described presumed the existence of an undesirable condition which required correcting. The new Ternstedt system was to be designed to avoid any foreseeable undesirable conditions. It was necessary, therefore, to make some broad assumptions in the design, since there could be no information on the analysis of the expected contamination.

An important part of the design was the planning of the arrangement and operation of the new metal plating operations. Decisions finally were reached that the plant would contain not less than five nor more than ten fully automatic plating machines. These would provide for copper, nickel, and chromium plating. In addition, a new automatic, zinc barrel plating machine would be installed along with two existing zinc plating machines located in the present building. In the

new disposal system, the cyanide wastes from these zinc plating machines would be diverted from the process waste system and collected in a sump in the area. These wastes would be pumped overhead to a cyanide waste line to be installed in the new building. The water conservation program would apply to the new equipment to conserve water and concentrate the wastes.

Separate pipe lines would be used to transport the cyanide waste to the treatment plant to keep this waste segregated from general process waste. Three 3-in. pipe lines were to be provided to run overhead in the building and below ground outside. All lines were to be rigid poly-vinyl chloride below ground and the chromic acid and demineralized water line was to be rigid poly-vinyl chloride inside. The cyanide lines would be black iron, all welded and flanged construction above ground. The rinse water would flow by gravity to the proper sumps where submerged impeller pumps would pump the material. Dual alternating float-controlled pumps would be used.

After further discussion and checking it was presumed that the following conditions would exist. The total quantity of industrial waste would not exceed 30,000 gph. The cyanide rinses, consisting of copper cyanide and zinc cyanide, would be completely segregated and transported to the treatment plant for complete destruction. Originally, liquid sodium hypochlorite was considered for destroying cyanides. After later calculations on the economy of this operation were made, the method was changed to alkaline chlorination, using liquid chlorine with hydrated lime for pH control, on a batch treatment basis.

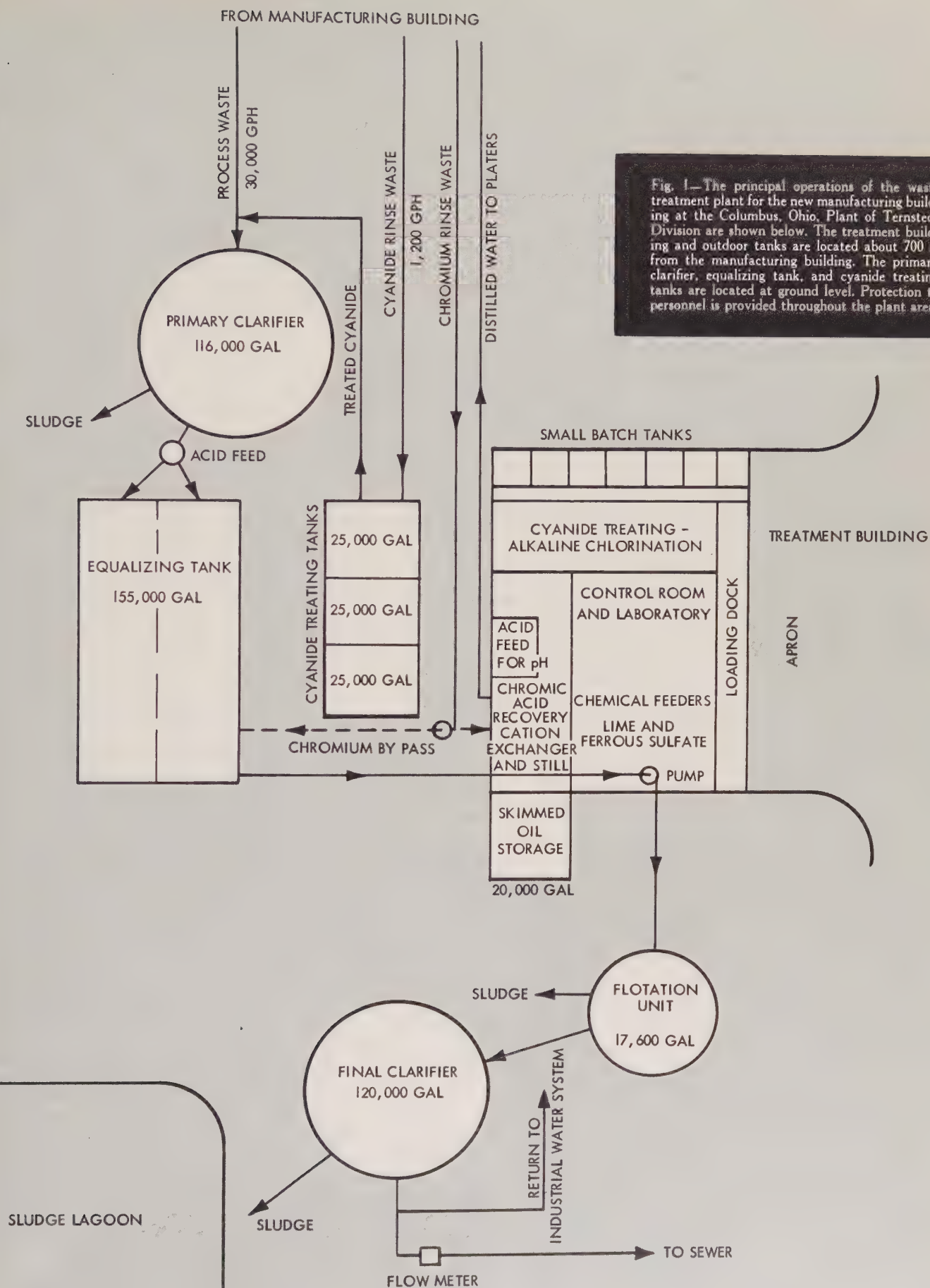


Fig. 1.—The principal operations of the waste treatment plant for the new manufacturing building at the Columbus, Ohio, Plant of Ternstedt Division are shown below. The treatment building and outdoor tanks are located about 700 ft from the manufacturing building. The primary clarifier, equalizing tank, and cyanide treating tanks are located at ground level. Protection to personnel is provided throughout the plant area.

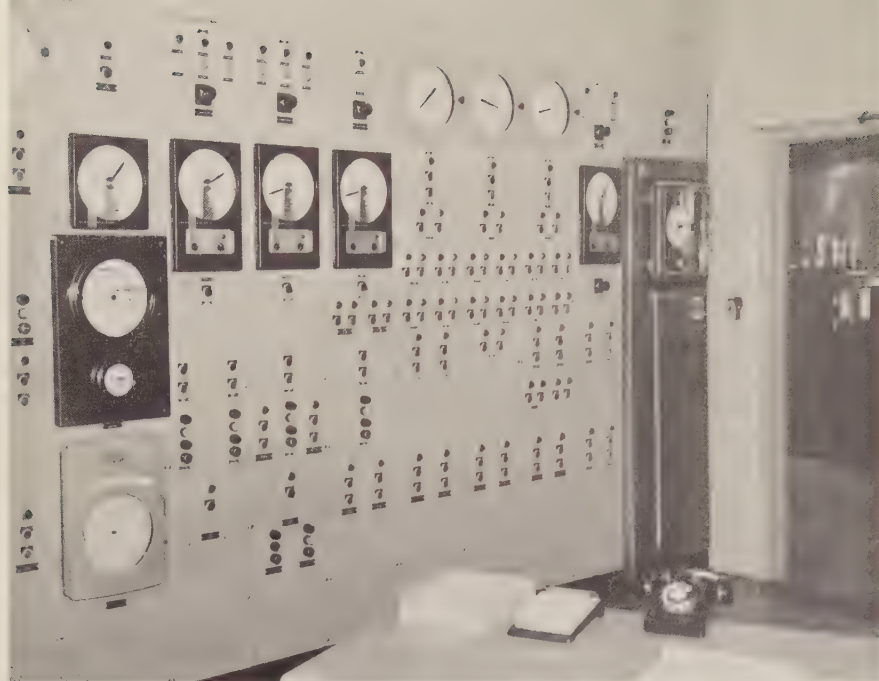


Fig. 2—The automatic control panel for the disposal system is located on the first floor of the treatment building. The view above shows the recording-controlling pH meters (left center), tank depth gages (top right), and oxidation-reduction potential ORP meter (far right). All measuring cells for determining pH values are arranged for convenient operation and maintenance at the extreme left end of this panel (now shown in the above view).

The chromium rinses would be transported to the treatment plant and the chromic acid would be recovered for re-use in the plating machines. Distilled water from this recovery would be returned for use in plating rinses.

All of the heavy metallic ions would be removed from the general process waste by alkaline precipitation and gravity separation. In the absence of a definite code or regulation establishing the type of effluent which could be discharged, it was decided to adopt the following requirements for the waste treatment plant:

pH.....	5.0 to 10.0
Iron.....	15 ppm
Copper.....	1 ppm
Chromium.....	2 ppm
Nickel.....	1 ppm
Zinc.....	2 ppm
Ether Solubles.....	20 ppm
Cyanides and Cyanates..	0.5 ppm.

Since the designs of the manufacturing plant facilities and the waste treatment plant were being made concurrently, it was possible to select the best arrangement for plating operations to simplify the problems of the waste treatment plant. In all plating machines, triple counter-flow rinsing would be used. The last station of all plating tanks would use a

fog spray rinse followed by an elevated drain station to reduce dragout by draining the solution directly back into the plating tank.

The plating pits were designed so that all cyanide or chromium bearing wastes could flow only into a sump. This would allow these wastes to be pumped to the waste disposal plant through separate pipe lines, segregated from the general process waste.

Specifications Selected for Treatment Plant

After establishing the general requirements for the waste disposal system and for the operation of the plating machines, the plans for the waste treatment plant were finalized. The treatment plant would be located approximately 700 ft from the manufacturing building (Fig. 1). The distance from the main plating area would be about 1,300 ft.

The cyanide waste would be piped to one of three 25,000-gal concrete tanks where it would be chlorinated at automatically controlled pH. Also, an oxidation-reduction potential (ORP) meter would be provided to indicate the changes taking place. The destruction would be complete in that both cyanides and cyanates would be destroyed. The treated water would then enter the general waste

treatment flow for clarification.

Due to the variation in dragout of various production parts and the wide variation in rinsing techniques, there is no reliable information on capacities for chromium recovery systems. For this application, it was estimated, therefore, that the recovery system should have a capacity of about twice the theoretical minimum flow as calculated for triple counterflow rinses. This required that the plating machines be designed and operated with an absolute minimum of rinse water to give maximum chromium concentration and minimum volume.

Chromium-bearing waste would be piped to a 6,000-gal holding tank from which it could be passed through a cation exchanger into another 6,000-gal catexed chromium holding tank and then into a glass lined vacuum still of 6,000-gal-per-16-hours capacity. Distilled water from chromium recovery would go to a demineralized water pressure system to supply pure water for plating rinses and bath make-up. Supplementing this would be a mixed bed demineralizer to make up for system losses and to serve for standby use. Also, provisions were made to divert chromic acid rinses into the process waste any time they became too dilute for economical recovery.

The general plant effluent would flow into a 45-ft diameter, 116,000-gal primary clarifier which would remove heavy solids and skim the floating oils. Skimmed oil would be stored in an existing 10,000-gal underground storage tank. At this point the pH of the waste flow could be automatically adjusted and recorded. From here the waste would flow into a 155,000-gal equalizing tank. The equalizing tank would be made from the existing settling basins by the addition of six mixers to provide agitation for acid mixing, to prevent settling at this point, and to equalize the effect of momentary high concentrations.

From the equalizing tank, the waste would be pumped into an air flotation unit at a pH of 4 or 5, depending on whether or not chromium was present. Here, ferrous sulphate would be added at a predetermined rate. The suspended oil would be floated off and lagooned with the sludges.

The effluent then would go to a final clarifier, a 40-ft diameter recirculated sludge clarifier with a chemical mixing well where lime would be added to bring the pH within a range of 9 to 9.5. This

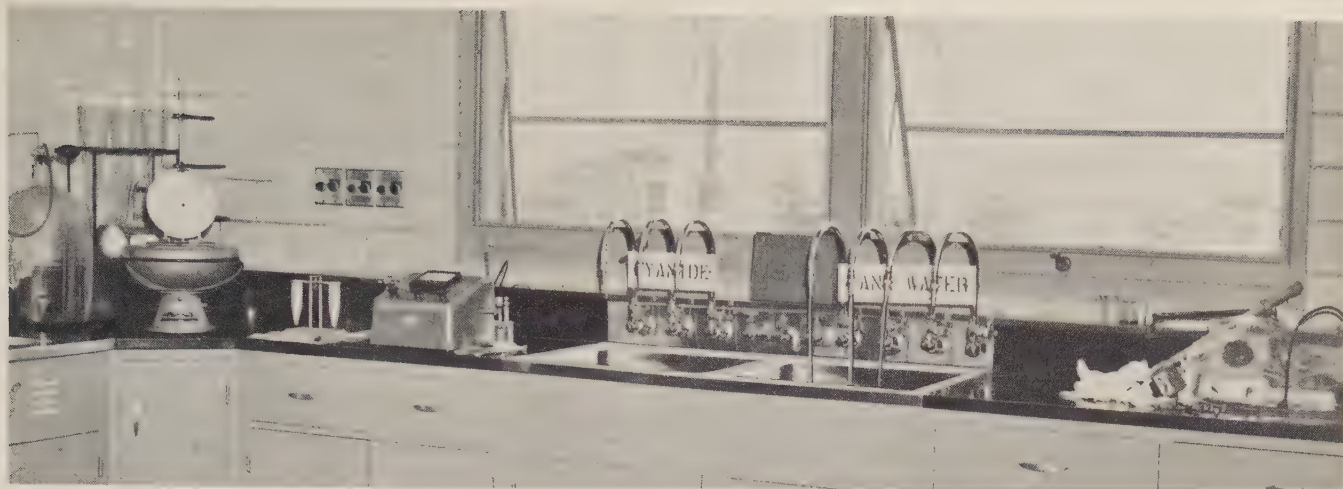


Fig. 3—Another interior view of the control room shows the sink taps to which samples from any of the treatment tanks can be pumped for test purposes.

Operation of Treatment Plant Proved the Design

mixing would be controlled by an automatic pH control on the lime feeder. The sludge would be blown off by gravity at timer-controlled intervals into a 20,000-gal sludge storage tank from which it would be pumped to the sludge lagoon. The effluent from the final clarifier then would flow into a sewer where it would join the sanitary wastes and flow into the Columbus sewer system. A portion of the effluent would be returned to an industrial water system in the waste plant to be used for chemical mixing, still condenser cooling, and washing down operations. Cooling water requirements for the still condenser would be 375 gpm.

Sludge handling would be done by both pumping and gravity blow-off, with sludge from the primary clarifier being pumped directly to a sludge lagoon. Due to the higher elevation of the flotation unit and final clarifier (above ground), sludge from these tanks would be blown down by gravity into a sludge storage tank and pumped to the lagoon intermittently. Clear supernatant liquid from the lagoon would be recirculated by gravity through the system entering at the primary clarifier inlet.

The entire waste disposal system was designed to require the minimum of personnel and afford a maximum of flexibility. All major valves would be remote air operated to be controlled from a central control room which also would contain all of the recording-controlling pH meters, flow gages, and tank depth gages (Fig. 2). All cells for measuring the pH values would be located in the control room. Samples would be pumped to the pH cells or to a sink where test samples from practically any process could be obtained (Fig. 3).

The waste treatment plant began operation in September 1956. During the first year, the treatment plant operated on two shifts. This was possible because the equalizing tanks could be emptied sufficiently to collect all of the third shift effluent from the manufacturing plant which was then held for treatment on the operating shifts. In September 1957 the volume of effluent increased making it necessary to add the third shift to the operation of the treatment plant. The plant is manned by an operator and an assistant on each shift. Safety precautions are taken throughout the plant and yard area.

The waste treatment building is a two-story brick structure, with basement and has a total volume of about 150,000 cu ft. The basement contains all pumps, chromic acid holding tanks, cation exchangers, industrial water tanks, and de-ionized water tanks. Located on the first floor is a chlorine room with scales for four, one-ton chlorine containers, an evaporator to supply the necessary heat for vaporization, and a chlorinator. The first floor also includes the central control room, laboratory, five lime feeders, three coagulant or ferrous sulphate feeders, a glass lined vacuum still, and a saturation tank for the air flotation unit. A loading dock is provided at the first floor level for the receiving of chemicals. An electrically powered monorail hoist permits unloading chlorine containers directly from the delivery truck. The second floor is used

for chemical storage and loading of feeder hoppers as well as a locker room. All floors of the building are serviced by a freight elevator.

At rated capacity of the plant the following volumes and retention times exist:

	Volume (gal)	Retention Time
Primary clarifier	116,000	3.8 hr
Equalizing tanks	155,000	5.2 hr
Saturation tank . .	500	1 min
Flotation unit . . .	17,600	35 min
Final clarifier . . .	120,000	4 hr.

In an average month, 10 million to 12 million gallons of water are discharged as well as 300,000 to 400,000 gallons of treated cyanide rinse water at 600 ppm. This requires approximately 20 tons of lime, 17 tons of ferrous sulphate, 6 tons of chlorine, and 14 tons of sulphuric acid.

Conclusion

Throughout its first year of operation, the new treatment plant has met the design requirements. In general, it has been able to produce an almost colorless, clear effluent. Completely absent are any detectable cyanides, cyanates, chromic acid, or copper. Sludge collection presented a problem because the sludge was produced faster than anticipated in the design of the system. This condition was corrected by the construction of a second lagoon approximately one acre in area.

At full capacity of the manufacturing plant, the waste treatment plant operates at about 60 per cent of its full potential. Thus it provides a reserve for any increases in waste discharge or for possible expansion of the Ternstedt Columbus Plant.

Research As Applied To Traffic Engineering

By DR. LAWRENCE R.
HAFSTAD
Vice President in charge of
Research Staff

Research can increase
safety by improving
the driver's competence



The problems of traffic engineering have been the object of a great amount of public attention in recent years. Mounting death statistics, discourteous driving, excessive speeding, and many other similar terms have become frequent topics of conversation throughout the country. In an effort to promote traffic safety, much has been done to improve roads and perfect automobiles. But the importance of driver motivation and response generally has been neglected. These neglected areas of traffic safety are not fruitless, but can be made to yield new ideas for safety through research. New approaches to traffic safety might help to solve the problems which exist. One new method could be the "mixed team" approach, where competent amateurs are included in planning sessions to give a fresh outlook on problems. A fresh, stimulating outlook on traffic safety can be of great help, and research can provide that outlook. For research is the effort of the mind to comprehend relationships which no one has previously known.

EVERYONE in the United States is interested in cars, and gradually becomes a self-appointed expert on how cars ought to be made. No doubt traffic engineers have had the same kind of experiences with respect to advice on traffic control. My background is such that I cannot claim to be an expert in this field, but since I have had considerable experience

*This paper is based on an address delivered by Dr. Hafstad at the 27th annual meeting of the Institute of Traffic Engineers.

in the research field it may be of interest to offer some of my impressions as a professional research man coming seriously in contact with the so-called "traffic problem" for the first time. I recognize that this problem has a number of facets and I would like to deal for the moment with one—traffic safety. Traffic safety is composed of three elements—the road, the car, and the driver.

While the fields of road design and of

car design have been pretty thoroughly explored, I think that there are still some areas here that can benefit from research. It is clear that the short range immediate problems are being competently handled by experts. But how about the longer range problems of ten and twenty years from now? Solution of these problems will require considerably more emphasis on research than in the past.

We have come a long way from the dirt roads of the past generation to the expressways of the present. Clearly an expanded and improved road system represents one of the greatest single steps which could have been taken toward greater safety on our roads. The national highway building program gives us the opportunity, if we can move fast enough, to incorporate rapidly into the system new things developed through research. It is both an opportunity and a challenge. As the record will show, traffic engineers have done well, extremely well, in the past, but "Whatever is done well can be

done better, and whatever is good can be improved." This must be our creed.

Returning now to my strictly personal reactions, first and foremost I am impressed by the extensive literature and the enormous compilation of data with which the neophyte in this field is confronted. I have rarely started reading in a new field where I have found it so hard to come to grips with the core of the problem. One quickly gains the impression that while it is generally considered that there are too many accidents, as a nation we seem unprepared to pay the price required for a further reduction of accidents. This leads to a school of thought which seems to feel that further research is useless since we already know of more things to do than the public is prepared to finance. Accordingly, scattered throughout the literature there are repeated references to the enormous complexity of the problem, and there occur alternately hysteria and overtones of hopelessness which seem to me, as a newcomer, totally unjustified. To a research man a problem begins to look hopeless only when all conceivable approaches have been explored to a bitter dead end. In connection with the traffic problem, we seem to have done a pretty fair job in seeing what can be done with concrete, steel, and asphalt. But there are almost an infinity of other approaches to the problem which have long remained, relatively, almost untouched. I am convinced that more progress can be made in traffic safety by emphasizing the relations between the driver, the signalling system, and the road, than by undue emphasis on a crash-proof car—which could lead us into the progressive stalemate analogous to the classic conflict between projectile and armor plate!

What Research Is

By the above statements I am implying obviously that in my opinion not much research, and certainly not enough of the right kind of research, has been or is being done on the transportation and traffic problems. This may seem a shocking statement to some who are already deluged with statistics. However, I have two comments to make in defense of my contention. The first is that the transportation industry as a whole is so fantastically large that a trivial percentage effort in data collection is bound to give a large volume of statistics. The second comment is that collecting and compiling

statistics is of itself an essentially sterile and uncreative activity and does not justify the name of research.

It is always helpful to define precisely the terms we use in a technical discussion, so I offer the following as a definition of research in the sense in which I will use it:

"Research is *not* constructing and manipulating; it is *not* observing and accumulating data; it is *not* investigating or experimenting; it is *not* getting the facts—although each of these activities may play an indispensable part in it. Research is the *effort of the mind* to comprehend relationships which no one has previously known."

It is this kind of research which I suspect and contend has had too little

support in relation to the extremely rapid growth of the transportation industry itself.

In the research business it is commonly stated that a precise formulation of a problem places one 80 per cent of the way along the road to its solution. After a considerable amount of reading in regard to the traffic safety problem, it remains unclear to me precisely what is desired and by whom. Certainly this would be a most fruitful area for the kind of research which I envisage as being needed. Here is an area where the semantic noise level is high indeed.

Some Statistics Can Be Misleading

Let us now seek to develop some perspective on this problem of automotive safety and to establish a few anchor points

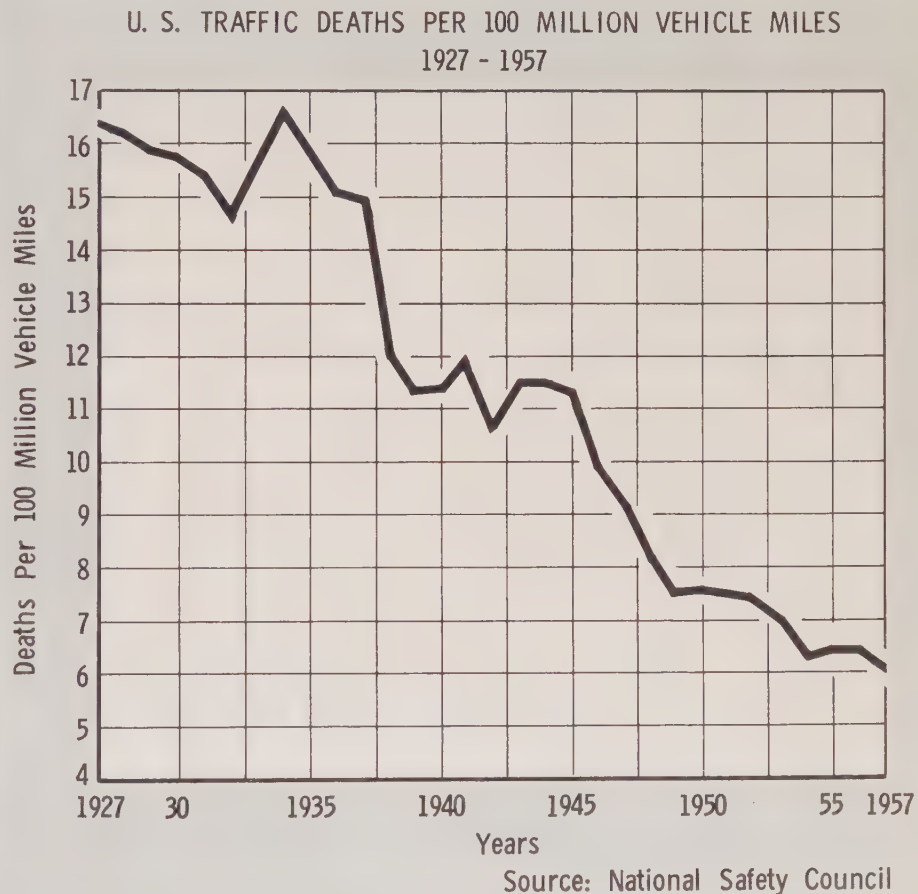


Fig. 1—To develop some perspective on the problem of traffic safety, it is necessary to examine the facts about traffic fatalities. For example, the above plot of the U. S. traffic deaths per 100 million vehicle miles for the years since 1927 indicates a desirable trend toward safer automobile travel. Yet, some confusion exists because the absolute magnitude of traffic deaths is higher.

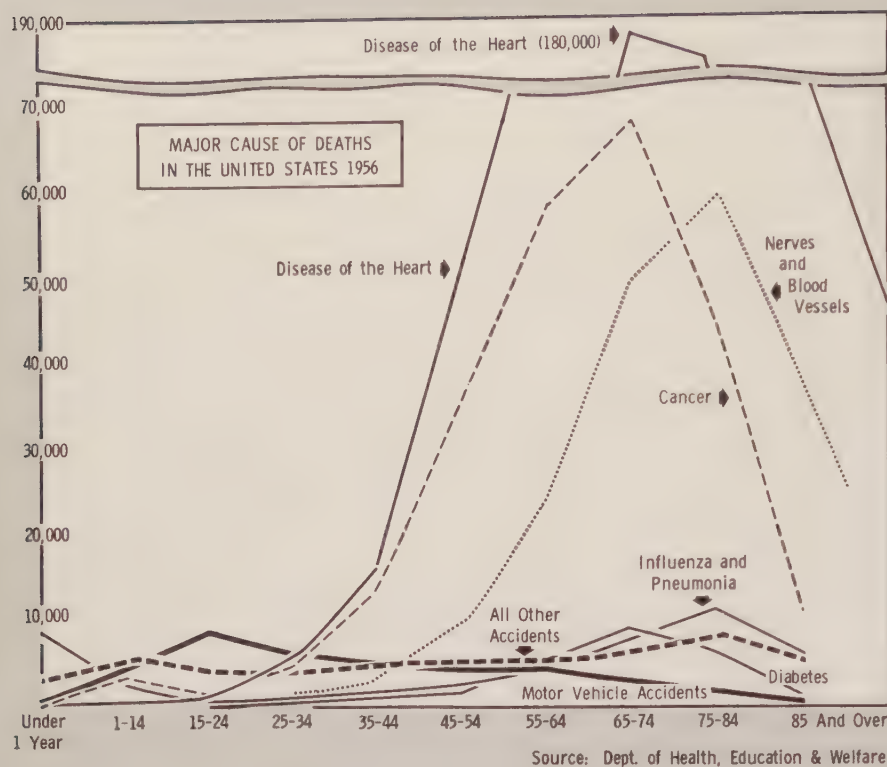


Fig. 2—The facts about the major causes of death in the United States also are of interest in studying traffic safety. The above chart shows that total deaths due to motor vehicle accidents are small in comparison with deaths due to various diseases. However, the number of motor vehicle accident deaths is highest when deaths from most of the other causes are lowest—during the early adult age years. This suggests the importance of efforts to reduce these accidents.

for comparison purposes. Traffic engineers are familiar with the trend curve for traffic fatalities per hundred million miles of travel (Fig. 1). The indication is that automobile travel has become steadily safer, yet the popular literature seems to indicate the opposite. This is confusing. Perhaps then the trend is satisfactory but the absolute magnitude is intolerable. Two things stand out when we examine the major causes of deaths in the United States in 1956 (Fig. 2). First, the total deaths due to motor vehicle accidents are small compared to deaths due to cancer and diseases of the heart, nerves, and blood vessels. Second, the fatalities due to auto accidents are highest in the age groups from 15 to 45, which is just in the minima for other causes of mortality. This begins to give a hint as to the reasons for the special concern over traffic fatalities and injuries. Instinctively we feel that they are or

should be unnecessary. Assuming agreement that this accident rate should be still further reduced, it becomes a technical problem to explore various means whereby this can be done. How vigorous should this effort be? This will be largely determined by the cost.

For additional light on this question, it might be helpful to compare further the traffic hazard to other hazards to which we are normally exposed. The results from one of Dr. Hardin Jones' studies¹ are particularly interesting and revealing because they are given in terms of "relative displacement of physiological age" or probable shortening of the individual's life span (Table I). From this comparison we can draw the significant conclusion that while very real, the traffic hazard (being represented by an average life span reduction for a driver or car rider of approximately 1.3 years) is less than the hazard of being say, 25

per cent overweight.

Thus, the serious student of the hazard problem can begin to understand the reason for the often-deplored "public apathy" toward accident reduction campaigns, be they for the use of seat belts or driving speed reduction. Let me emphasize again that this is no excuse for discouragement on the part of those of us committed to a still further reduction in the accident rate. We have merely been able to specify one of the boundary conditions of our problem and that is that the public will be all for further accident reduction only if it will involve relatively little effort or inconvenience on the part of the driving public.

Have we perhaps reached the point of diminishing returns where each further increment of accident reduction can only be made at greatly increased cost? This is a fair question and a pertinent one. It is my impression that very rapid progress is really still being made. I cite as evidence the oft-quoted figures for fatalities on controlled access highways as being one third or one fourth of the national average. I cite further the report from Connecticut that with strict enforcement the fatality rate was dropped 11.7 per cent in 1956, while the national average was increasing by 5 per cent. These are very significant gains indeed, and suggest that attacks on other fronts might be equally rewarding. The problem for the traffic engineer is to ensure that so far as possible the effort and money be spent where the greatest return will be possible for the least cost. This brings us back to the research problem, for to determine this a lot of partial derivatives will have to be evaluated.

The Driver is Important in Traffic Safety

It is my impression that traffic engineers have been so preoccupied with the road and the car that they have relatively neglected driver motivation and responses. As a trivial example, would it be cheaper and more effective to place more adequate signs along a given stretch of road before a turn than to add another lane? It is clear that here we are up against just the kind of need for optimizing which is typical of systems engineering problems. The systems engineering approach, with its companion technique of operations research, is widely used and highly developed in the communications industry, in the aircraft industry, and in the

RELATIVE DISPLACEMENTS OF PHYSIOLOGIC AGE BY FACTORS THAT ACCENTUATE AGING (MINUS TIME) OR RETARD AGING (PLUS TIME)

	Reversible	Years
Country vs. city dwelling.....		+ 5
Married status vs. single, widowed, divorced.....		+ 5
Overweight		
25% overweight group.....		- 3.6
35% overweight group.....		- 4.3
45% overweight group.....		- 6.6
55% overweight group.....		-11.4
67% overweight group.....		-15.1
or, an average effect of 1% overweight.....		- 0.17
Occupational exercise vs. sedentary occupation.....		+ 5.0
Smoking		
1 pack cigarettes per day.....		- 8
2 packs cigarettes per day.....		-12

STATISTICAL DISTRIBUTION OF LIFETIME SHORTENING BY TRAVEL AND INDUSTRIAL ACCIDENTS. (VITAL STATISTICS OF 1949, ADULT WHITE MALES 20 YEARS AND OLDER)

	(Per Individual)
All accidental deaths.....	-2.3 yr—U.S.A.
Travel Accidents	
Railways.....	-0.06 yr—U.S.A.
Ships.....	-0.04 yr—U.S.A.
Motor-vehicle, driver, and passengers.....	-0.67 yr—U.S.A.
Assuming only ½ of population spends time in automobiles.....	-1.3 yr—at risk
Pedestrian motor-vehicle.....	-0.2 yr—U.S.A.
Assuming this effect largely involves urban population.....	-0.4 yr—U.S.A.
Aircraft.....	-0.05 yr—U.S.A.
Assuming that ¼ of population (probably less) uses airplanes.....	-0.2 yr—at risk
Accidents—Industrial Machinery.....	-0.04 yr—U.S.A.
Assuming only 30% of males are employed on industrial machines.....	-0.27 yr—at risk

Values based on numbers of deaths attributed to accidents. Estimates of life span lost are slightly low because survivors who are maimed, with reduced life expectancy, are not included.

Table I—Of further interest to studies of traffic safety is information about various conditions and hazards which affect life span. The above data were compiled in studies by Dr. Hardin Jones¹ and they are given in terms of probable shortening of an individual's life span. These comparisons indicate that effect of traffic hazards on shortening the life span (1.3 years) is less than several other hazards. This suggests a reason for the often-deplored "public apathy" toward accident reduction campaigns.

missile business. It seems to be urgently needed in connection with the traffic problem.

One reason for this statement is that in connection with such studies in other fields it has become standard practice to use the "mixed team" approach with a generous infusion of "outsiders." During

and since the war, it has been repeatedly demonstrated that it is mainly from such teams of highly competent amateurs that one gets refreshingly new approaches to old and seemingly insoluble problems. The very slogan "Engineering, Enforcement, Education" might suggest that the human problem outweighs the engineer-

ing problem two to one. Are traffic research investments made in anywhere near this ratio? In the sample of the research literature which I have been able to cover, I find the contributions of the psychologists and biologists to be a still small and somewhat squeaky voice.

Suppose we had adequate financial support and a large number of such study teams. What kind of problems could be assigned to these groups, and what kind of results would we have a right to expect? As I have stressed before, it seems we must try to determine just what relative emphasis the public wants to have placed on the often conflicting requirements of mobility and safety. Just as a starter and as a first approximation we can turn to a recently reported Gallup poll study², which lists the driving public's own suggestions for reducing the number of highway accidents in the order of frequency of mention. It is significant that stricter law enforcement should be the first on this list. This is very much a "human" problem.

Bearing on the same problem is a report from the recent excellent work at the Yale Bureau of Highway Traffic, to the effect that the chronic violators on U.S. highways invariably turn out to be intolerant, aggressive, resentful of authority, and with a high opinion of themselves. Will this situation be changed in the slightest by more acres of concrete?

Still more fundamental, so far as long-term trends are concerned, would be the question of the real efficacy of the current campaign for "defensive driving." Laudable as this campaign may appear, as a scientist I have to ask the embarrassing question: What is the probable half-life of the defensive component of the population if the offensive component (the above mentioned "intolerant, aggressive and resentful" component) continues over the years to be rewarded with right-of-way privileges normally reserved only for visiting chiefs of state? In plain English, how long will it be before the defensive driver is either "bumped off" or converted into an aggressive driver, if it is the latter who always wins? Trends are usually determined by the forces acting. It seems to me to be a fair question to ask what psychological forces are acting on the driving public?

Still further along the same line, I find of interest and significance the statistics reported from the psychopathic clinic of Detroit at the Second Highway

Safety Conference where 19 people had had 225 tickets for violations in 128 man-years of driving. With the most elementary application of sequential analysis to the statistics of violations, such individuals must surely stick out like a sore thumb. Yet the well-intentioned driver is charged with providing right-of-way for these people, while the law enforcement officer is expected to retain both his morale and his good nature as he patiently tags the same violators year after year. Does this really make sense?

Still speaking of the enforcement problem, I would stress as a very fruitful area of research the relations between the driving public and the enforcement officers. How large percentagewise is the "well-intentioned" part of the driving public, and what determines this percentage? Certainly laws and regulations can be devised so that, say, 90 per cent of the driving public favors them. Should not some effort be made to provide instrumentation for assisting the officer to close in on and eliminate the careless driver and chronic violator?

I have touched upon only the first of the ten suggestions made by the driving public for reducing accidents. Each of the others could be equally stimulating as a source of important research problems if they were to be adequately and imaginatively explored. "There is gold in them thar hills!"—but to begin to extract it, it will be necessary to invest a much greater proportion of highway funds into research than has been the custom in the past.

A Fresh Approach Can Be Beneficial

To get maximum return from such research, I would like to urge greater use of the mixed-team approach which I have already mentioned and which is so successful in other fields. To get what I would call refreshingly new and different approaches to the traffic problem, it would be necessary to support the novel and interesting rather than only the obviously practical. I hope we need not repeat the errors of those who, in the early days of the war, were proudly and hopelessly intolerant of anything they considered impractical, even in research. The point is that no research man expects anything impractical to be introduced either on the battlefield or on the highway; however, to get one idea which is both novel and practical he must be allowed to explore ten ideas which are

novel but of which nine prove impractical.

For another example, let us turn now to the field of car and highway instrumentation, for this is a field which I feel should prove to be particularly fruitful of results in our continuing campaign both to increase mobility and decrease accidents.

First, let's ask ourselves if there is anything we can do to help the enforcement officer eliminate the chronic violator fringe. Upon reflection and with only very little effort and imagination we can conceive of an entirely new category of car instrumentation which we can call driver monitors. Since excessive speed is given as the "cause" for most accidents³, speed becomes of interest especially after an accident, for I gather from my background reading that there are occasional differences of opinion between the "collidor" and the "collidee" (Table II). If I were an enforcement officer I would become impatient with testimony to the effect that a car going only thirty-five miles an hour unexpectedly left the road and plowed through trees, barns, and fields before coming to rest.

If we are serious about persuading people to obey speed laws, why not introduce the use of a speed monitor that records speed continuously on an endless magnetic tape, retains the record for the last five minutes, and wipes out the previous record? In this case one would imagine the monitor kept in a sealed case during all normal driving and that it would be requisitioned by the authorities after an accident when the need for just such objective information becomes crucial. Is this practical? That depends upon how badly it is needed. Is it technically feasible? Most assuredly. A laboratory version of such an instrument with the play-back device and final

record has been proven successful. Are we really serious about law enforcement, or are we just talking?

Clearly there are an infinite number of variations of such a monitoring device. Accelerations could be recorded to identify the "jack rabbit" type of driver. Or, if desired, the total number of times a driver improperly crossed a "no passing" pavement marking could be recorded.

Another type of monitor, and probably more practical, might be developed. We have all become familiar with the radar installations at roadsides. These transmit a signal to enforcement officers when the speed limit is being exceeded, but it seems to me very bad psychology indeed that no signal is recorded in the offender's car. With simple instrumentation a relay could be provided in the car which, coupled with the roadside device, might flash a warning light or initiate a persistent raucous sound. With the addition of a veeder counter, again in a sealed container, the number of annual violations would be available for perusal by the authorities.

As I have said, the variations are limitless, but with cards stacked so heavily in favor of the violator as against the law-abiding driver, perhaps some of them should be looked at seriously. The above suggestions are cited not necessarily as recommendations, but as examples of the kind of unconventional ideas which are likely to emerge if more of a mixed-team or operations research approach is introduced into the traffic problem area.

Still trying deliberately to be stimulating rather than practical, and to generate novel ideas and new lines of thinking, let me ask a few questions about the instrumentation on our current model cars. This is an area more the responsi-

VIOLATIONS MOST COMMONLY REPORTED IN FATAL ACCIDENTS (94% OF THE TOTAL) DURING 1956

Excessive speed	47%
Wrong side of road—not passing	13%
Disregard of officer or traffic control device	10%
Failure to grant right-of-way	10%
Improper passing	5%
Under the influence of alcohol	5%
Improper turns	4%

Table II—The violations involved in fatal accidents indicate that excessive speed is the cause in the largest percentage of cases. This suggests study of ways to persuade people to obey speed laws.

bility of the manufacturer than of the highway engineer, but with the systems approach we must concern ourselves with all aspects of the problem and surely the driver-to-instrument link is an essential one in the chain of relationships from driver to road and back again.

Pondering this problem as a layman and strictly as an amateur, I ask myself what information I want as a driver rolling along an expressway, and then try to note whether or not I am adequately serviced. It is my impression that there is much room for improvement in this area—if we can be prepared to make a break with tradition as drastic as that of styling in recent years. As a driver I would like to know, continuously and with my eyes continuously on the road:

- That I am running at a safe speed for that particular section of highway under such specific road conditions as snow and ice that prevail at that particular time
- That I am within the legal speed limit
- That I have at least enough gasoline to reach the next gas station
- Whether or not there are cars approaching from the rear, right rear, or left rear
- Whether or not I could safely pass a car ahead in the face of oncoming traffic
- Whether or not, if I could pass a closely bunched group of cars just in front of me, I could find open road ahead
- Whether or not I have fallen or am falling asleep
- How often this section is patrolled to provide aid in case of breakdown.

With my eyes on the road where they belong, my instruments tell me none of these things. Regarding some I can get partial information with furtive stolen glances. Regarding most I get no information at all.

At the other extreme, perhaps different instrumentation is needed to tell the driver more about the actual performance of the engine and other components of the car, even when standing still.

While these latter problems fall in the bailiwick of the automotive designer, I cite them to suggest that perhaps two instrument panels might be desirable—one, (using either aural signals or visual signals within the view of the driver) for running conditions on an expressway, a second for engine performance analysis

at zero or near zero speeds. A trend in this direction might open a whole new chapter in road-to-driver signalling and communications systems. From the safety standpoint, once the two types of instruments are distinguished it would become possible to hinge, rotate, or otherwise automatically cover the low speed group at speeds above, say, 30 mph, so as to present on the dash board not angular instrument controls but a thick cushion of energy-absorbent plastic.

That such a switch in instrument panel philosophy is not unthinkable is indicated by current trends in the aircraft instrumentation field. It has been recognized, belatedly, that the pilot is not really interested in the exact number of gallons of gas in his various tanks. He is interested in his exact present location and the choices he has of alternate landing fields based on his present gasoline supply. This is simply and convincingly given by an electronic instrument map presentation with circles or residual range radius, centered on his present position point.

We have in the above touched upon one facet of the communications problem, but this is really one which has ramifications in a host of different directions all suggesting fruitful research areas. We have all experienced the curious discourtesy of the average driver and there is frequent reference to it in the literature. Here is a problem so fundamental that we should have an assortment of psychologists hard at work on it. Not being a psychologist I must leave this field to others, but I cannot help but wonder how different car courtesy would be if cars could somehow say to one another, "Pardon me," "Thank you," and "After you, Alphonse."

A more technical facet of the same problem is that of signalling driver intentions and speeds to other drivers. Here is a whole area of driver communications which justifies intensive research.

Moving to a higher degree of sophistication in the communication and instrumentation fields, there is the interaction between the road signs and drivers. Most of us learn in about the sixth grade how to write so that we can be understood. Some of us spend the rest of our lives trying to learn to write so we cannot be misunderstood. In my opinion, the road signs and the signalling system of the car owe it to the driver to keep him so informed that he never breaks the law or takes unknown risks unintentionally.

Here our conventional system of speed limit and other signs seems inadequate. There is the sign whose meaning is obscure—the sign which is too small—the sign which is too close to the area it controls—the sign which has meaning only for the local resident—and so forth. The problem is not trivial, for more is at stake than the inconveniences of, say, one driver in a thousand. The bewildered driver is a hazard to all others in his vicinity. How great this hazard is, and how it can be reduced at minimum cost, gives us another research problem.

There are so many possible avenues for improving communication, each begging for more research, that I can mention only a few. The whole role of the subconscious in the driving operation seems to remain essentially unexplored. In observing my own driving carefully, I have found upon occasion that I come to a full stop for a flashing red warning light and wait indefinitely for the light to change to green! Apparently my subconscious has really learned the basic rule, "Never go through a red traffic light." Surely this would be a profitable area for research.

We have all experienced the problem of discerning a tiny red or green traffic light against a kaleidoscopic background of bright neon lights of all colors and frequencies of flashing. Would it help to take a page from the experience in the radio-communication field and reserve for traffic signals a frequency of, say, two cycles per second and carefully exclude all other signs from the neighborhood of this band? Under such conditions, perhaps with training the problem of locating and reacting to traffic signals could be transferred from a resentful and bewildered conscious to an automatic and dependable subconscious.

At a still higher level of sophistication, one might consider duplicating the traffic signals from the roadside, inside the car, where they would speak with considerably enhanced authority. This might involve a system of electrical cables buried in the pavement, but with a new road construction program just getting under way, even this is no longer unthinkable. Here the difficulty lies only in stepping up our research program so that it can be determined what ought to be done in time to have it incorporated in at least part of the construction program. In my opinion we are already late.

From cables for signalling to cables for

control is just another step in sophistication and cost. Such systems are sure to come for high speed expressways, and with adequate research such expressways can be expected to develop continuously toward both greater speeds and greater safety. If the arrogant and uncooperative minority of drivers can be eliminated, one can begin to conceive of expressways which can be made essentially idiot-proof.

I have tried to indicate above that research has much to contribute to the solution of what we call the traffic problem. Most of what I have said, however, refers to the problems of the open road. It should, therefore, be emphasized that the better expressways become, the more congested traffic in the urban areas will become. If cars spend less time *between* cities they must necessarily spend more time *in* cities. What is to be done about this local urban traffic problem, which has been relatively neglected? Here considerably more money invested in research would pay real dividends. The problem is clearly quite different from that of the open road—the emphasis being more on mobility and less on safety. This problem admittedly becomes extremely complex, but as it increases in complexity it also becomes more amenable to a statistical approach. This is an area in which the modern researcher has enormously powerful tools at his disposal. In this field the much publicized electronic brains come into their own. Simulators and analog as well as digital computers have their contributions to make.

Many traffic engineers are already familiar with developments in this field and are beginning to bring them into use. Traffic control devices which effectively count traffic in all directions at an inter-

section and adjust time intervals automatically to give maximum traffic flow are examples of such computers. From single intersections we can expect the application of such devices to be expanded to include networks of roads and eventually entire communities.

There is currently still such a shortage of technical skill in this field of computers and data processing that most of the available talent is being absorbed by military problems. As talent becomes available, and begins to show what contributions it can make in the traffic control field, I predict that traffic control gaming using these devices will become just as popular and productive as war gaming has been in the recent past.

The urban traffic situation does indeed present the appearance of a maze of insoluble problems. But other even more difficult problems have been solved by research. I am reminded of a statement made a little over 100 years ago by the great chemist, Wöhler, with regard to the status of organic chemistry at that time. Wöhler wrote to Berzelius as follows:

“Organic chemistry just now is enough to drive one mad. It gives me the impression of a primeval tropical forest, full of the most remarkable things, a monstrous and boundless thicket, with no way of escape, into which one may well dread to enter.”

Conclusion

I have tried to indicate why I feel that in spite of the admitted fact that we already know more about the solution of traffic problems than we can persuade the public to accept, there are still big dividends to be collected from more research in the transportation field, both

as regards mobility and safety. I am convinced that, relative to the work on the roads and on the car itself, the research in regard to the driver and his interaction with his environment has been neglected and such research should prove most fruitful in the next decade. Finally, I would urge that the large investment which we as a nation are about to make in roads should be adequately protected by sufficient research to ensure that these roads function effectively as part of the overall system involving the driver and his motivations, stimuli and responses, as well as the road and the car.

I am aware that an allocation of 1½ per cent of the new highway fund has been made for the purpose of “research, surveys, and planning.” My fear is that unless real research is vigorously defended, surveys and planning will quickly absorb these funds. One might hope that monies for surveys and planning might come from those assigned to construction. The best insurance we could have for a healthy traffic situation 10 to 20 years hence would be for the major part of this allocation to be invested in the kind of research I have tried to describe.

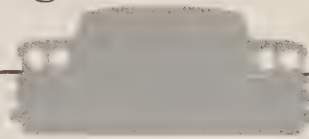
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Why Cars Have Four Headlights

By GEORGE W. ONKSEN
Guide Lamp
Division



Automotive headlight development has been based on reducing glare to oncoming cars and increasing road illumination. The automobile headlamp has progressed from the first electric headlight in 1908, through the Sealed Beam in 1940, to the present day development of the dual headlighting system. The new four-lamp arrangement provides lighting units specifically designed for upper and lower beams. This eliminates the necessary sacrifice of individual beam characteristics when both are placed in one lamp. The new system provides increased road illumination without increased glare. The development of the new headlighting system was hastened by the production of a mechanical method for aiming headlights.

THE history of automotive headlighting has been the story of a struggle to reduce the light producing objectionable glare to oncoming drivers and to increase the light which the driver needs for "seeing." The two objectives are in natural conflict, because a beam which illuminates the road far ahead for safe driving is too bright for the approaching driver.

Electric headlamps were introduced on automobiles in 1908. For many years headlamps had only one beam and various expedients were used to provide "seeing" without glare. The first headlamp beams were obtained from parabolic reflectors and plain window glass lenses. These beams were rather concentrated and were roughly round, like those from spot lights. Later, the glass lenses were made with a diffused inner surface to increase the beam spread. Cars were equipped with a special switch having one position which fed the lamp bulbs directly from the generator and a second position which fed the lamps through a resistor to reduce lamp brightness when meeting other cars. The name *dimmer switch* had its origin with this practice in 1916. Gradually, the science of automotive lamp optics developed in which the lens was divided into a number of adjoining elements so that different parts of the beam from the reflector could be spread sideways in varying amounts, by means of flutes, or directed up and down, by means of prisms. The resulting lamp beams had a high intensity area at the top, a fairly sharp cut-off above it, and a general, or base, beam of moderate spread sideways, and a small spread downwards.

The first attempt at a two-beam headlighting system occurred in 1921, when a lamp was built in which the beam could be raised and lowered at will by the driver by tilting the reflector up and down.

The invention of a bulb having two filaments in 1924 led to the introduction of headlamps with two different light beams: (a) an upper beam for distance visibility, and (b) a lower beam to reduce glare when meeting other cars. At first, headlamp beams were symmetrical; that is, both sides of the road were equally illuminated.

In 1932 nonsymmetrical lower beams were introduced. The nonsymmetrical lower beam projected more light down the right side of the road than the left, and the top of the beam was aimed higher on the right than on the left. The nonsymmetrical lower beam maintained glare relief for approaching cars and greatly improved the driver's distance seeing ability on his side of the road.

During this period, headlamp design and styling became highly competitive between manufacturers. National enforcement and safety groups persuaded the automotive industry to handle the headlighting problem on a cooperative and standardized basis. As a result, the automotive industry adopted in 1940 a standardized system of headlighting known as *Sealed Beam*. This standardized lighting unit and headlamp construction simplified service and law enforcement problems.

Late in 1954 an improved version of the original Sealed Beam lamp was put into production. Two basic improve-

New system permits full development of individual beam characteristics

ments were adopted; (a) the top of the lower beam was raised $\frac{1}{2}^\circ$ on the right side, and (b) a shield was placed in front of the lower beam filament to block off upwardly directed filament light to improve visibility in rain, snow, and fog.

In September 1955 Guide Lamp Division introduced a mechanical headlamp aiming system (Fig. 1). An integral part of the system was a lens on which were cast three reference points. During manufacture, the optical aim of the beams was related to the three reference points. In service, the headlamps were aimed by means of a mechanical fixture registering against the three reference points. The system permitted headlamps to be aimed in daylight in a matter of minutes by service station personnel.

Dual Headlight System Has Improved Lower Beam

Lighting engineers have long recognized the limitations in single Sealed Beam headlighting imposed by the necessity for compromising the optical design to provide both driving and passing beams from the same reflector and lens. Avoiding these compromises, the new Dual Sealed Beam system provides a definite improvement in roadlighting. This system consists of two dual headlamps, one pair mounted on each side of the car (Fig. 2).

The chief feature of the Dual Sealed Beam system is the improved lower, or passing, beam obtained from one of the lamps in each pair. This lamp has two filaments with the primary filament, reflector, focus, and lens design optimized to produce the best possible passing beam (Fig. 3a).

The upper beam is produced by all four headlamps. The secondary filaments

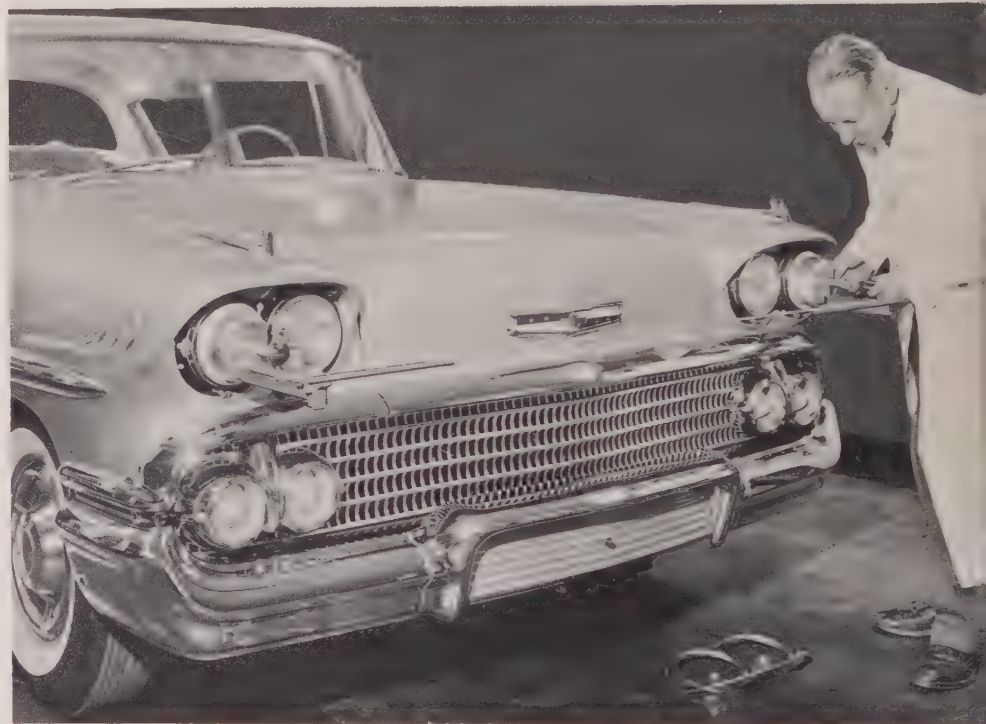
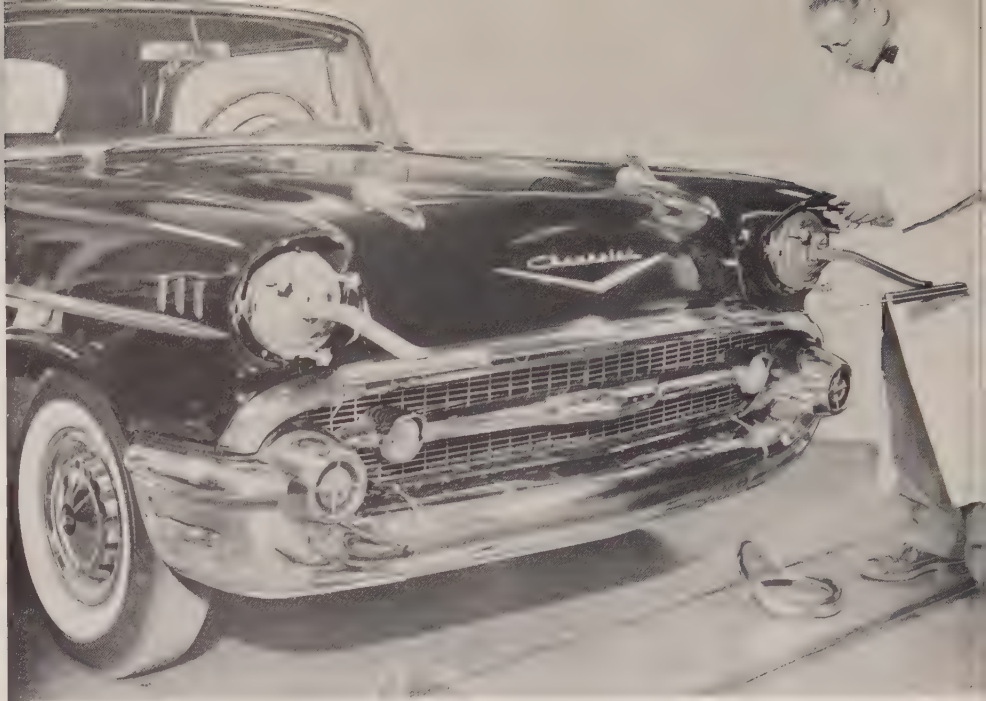
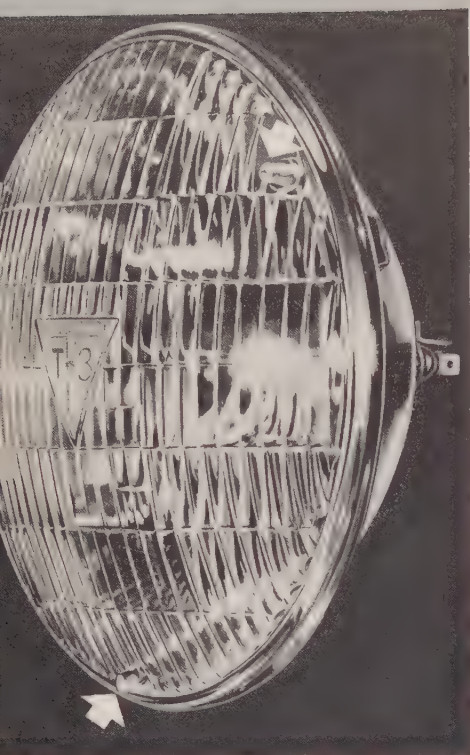


Fig. 1—In 1954 an improved version of the original Sealed Beam headlamp was introduced. Along with the new Sealed Beam headlamp came the introduction by Guide Lamp Division of the T-3 Safety Aim System—a mechanical system which greatly simplified headlamp aiming and adjustment. The T-3 system involved mechanically aimable headlamps and mechanical aiming devices. The mechanically aimable Sealed Beam lamps had three guide points cast into the lens (above). The guide points served as bosses on which the Safety-Aimer was seated. During manufacture, the headlamps were aimed electronically and the guide points were accurately ground so that when the plane formed by the guide points was mechanically aligned with the vehicle axis, the beam was correctly aimed. The aiming devices, known as Guide T-3 Safety-Aimers, were made in pairs—one device was attached to each headlamp with its face resting upon the guide points (top right). The aimers had individual spirit levels for vertical aiming and cross bars with a connecting spring-loaded string for horizontal, or lateral, aiming. Headlamps were aimed with the car in an unloaded condition on a calibrated, or level, floor area. Horizontal aiming was performed first. The horizontal aiming screw located at the side of each sealed unit was rotated until the cross bars of the aimers were aligned with the string. The lamps were aimed vertically by rotating a vertical aiming screw, above or below each sealed lamp, until the bubble in the spirit level was centered. When the horizontal and vertical aiming operations were completed, the aiming plane through the guide points was square with the vertical axis, and the headlamp beams were correctly aimed. Mechanical aiming was used exclusively on General Motors cars during the 1956 model year. This method of aiming has

now been adopted by the entire automotive industry.

The new Dual Sealed Beam headlamps also have three guide points cast into the lens. This allows the same easy and accurate mechanical aim for the new headlamps as used in the single Sealed Beam lamps. Each pair of lamps in the dual system is aimed separately (bottom right). The development of the mechanical aiming system played a major role in making the new Dual Sealed Beam system practical. Much difficulty would be encountered in aiming the asymmetric beam in the lower beam lamps if older type aiming machines were used.

in the two lower beam lamps supplement beams from the two single-filament lamps to produce a composite upper beam (Fig. 3b).

Why Driving and Passing Beams Are Different

Four headlamps give better lighting results and performance in terms of seeing distances because of the different beam

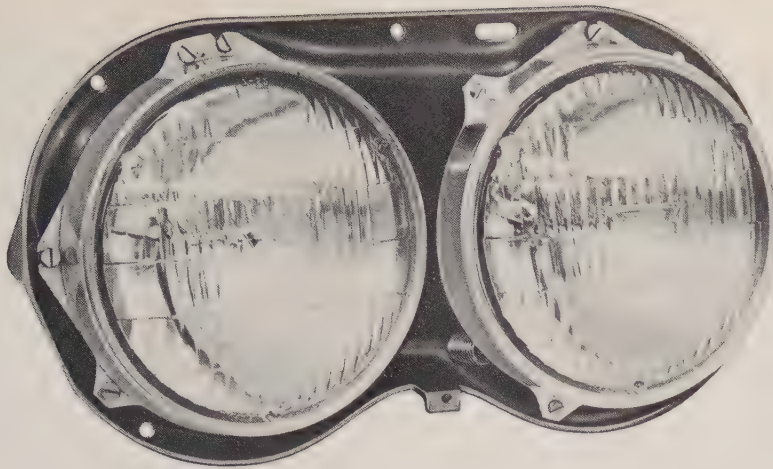


Fig. 2—To overcome certain limitations inherent with the Sealed Beam headlighting system, lighting engineers developed the Dual Sealed Beam system which consists of dual headlamps mounted on each side of the car. Each headlamp includes two sealed lamps mounted in a single housing. Provision is made in the new system for a lower, or passing, beam and an upper, or driving, beam. The identification numbers 1 and 2, molded into the lens, designate the upper and lower beam lamps respectively.

pattern requirements for upper and lower beams (Fig. 4).

For example, the upper beam must give relatively high intensities to provide seeing distances in excess of stopping distances, provide light to fill the entire width of the road, and provide light to see up hills, beyond dips, and around curves. This provides a good open-road driving beam but cannot be used when meeting oncoming cars. The lower beam must have sufficient intensity to provide good illumination when driving in in-

clement weather and to aid silhouette seeing. If both beams—the upper beam for the open road and the lower beam for passing cars—are to be provided by a single-headlamp lens-reflector combination, there must be a compromise in design.

Over the years, lighting engineers have developed a pretty fair compromise, both with the original Sealed Beam headlamp, and the improved Sealed Beam headlamp of a few years ago. However, the new four-lamp system permits one

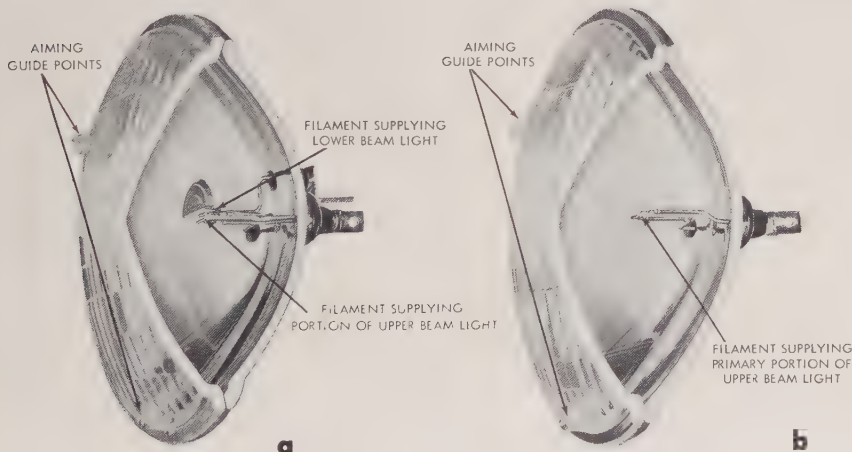


Fig. 3—This illustration shows the basic advantages of the dual headlighting system. Instead of compromising upper and lower beams in order to include them both in one lamp, the new system eliminates compromise by designing one lamp specifically for each beam. This permits full lighting benefits to be obtained from the lamps. The Type 2 lamp (a) contains two filaments. One filament, located at the focal point of the parabolic reflector, provides light for the lower beam. The filament location and the lens of the lamp, which are specifically designed for the lower beam, result in a greatly improved lower beam light. The other filament in this lamp is located below the focal point, and provides a portion of the light for the upper beam. The primary portion of the upper beam is supplied by the Type 1 lamp (b). This lamp has one filament, located at the focal point, and is designed specifically for the upper beam. Cast into each lens are guide points which serve as reference points for the mechanical headlight aimer (Fig. 1).

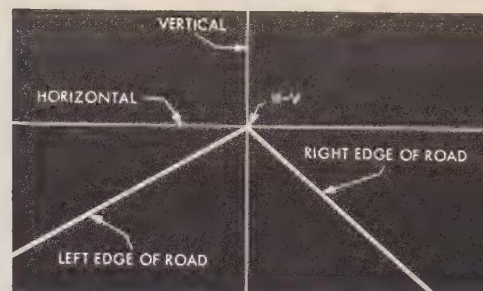


Fig. 4—This diagram shows a perspective of the road from the automobile's position on the right side of the highway. The horizontal line represents the height of the headlamp centers from the ground, and the vertical line represents a projection of the axis of the car. The intersection of these two lines is known as the *H-V* point in S.A.E. specifications and is the position of the oncoming driver's eyes at 1,000 feet or more, as well as that point where maximum illumination is desired.

To provide seeing distances in excess of stopping distances, the upper beam must provide relatively high intensities at the *H-V* point. This high intensity zone should fill the entire width of the road. There should be a lesser but considerable intensity directed above this high intensity zone to provide seeing distances up hills and beyond dips ahead. There should be light directed rather far to both sides at the level of the headlamp centers above the ground to help see around curves. There should be a base beam pattern below the horizontal to give an evenly lighted road surface from near the car to several hundred feet ahead and to the sides to illuminate the berms.

While this is a good open-road driving beam, it cannot be used to meet other cars. It is too glaring. Even aside from the problem of glare, the beam pattern is not ideal from the standpoint of the driver behind it. In the first place, most of this light in the upper left quadrant must be eliminated and the light for about a degree below the horizontal on the left side must be greatly reduced. To provide a satisfactory reduction in glare for negotiating right-hand curves, an appreciable amount of light above the horizontal on the right-hand side also must be eliminated. Furthermore, a considerably increased intensity should be directed further below the horizontal on the right-hand side to aid in seeing the right edge of the road while meeting approaching cars. Also, some added intensity should be directed lower down on the left side of the lower beam for use in driving in inclement weather and to aid silhouette seeing.

It becomes apparent, therefore, that these two beam patterns, the upper beam for the open road and the lower beam for passing other cars and driving in bad weather, are vastly different. It follows that if both beams are to be provided by a single headlamp lens-reflector combination, either the upper, lower, or both beams, must be compromised in design.

pair of lamps to be designed particularly for one beam. This offers a new opportunity for improvements by avoiding compromises.

Dual Headlighting System Has Improved Optical Characteristics

A better understanding of the Dual Sealed Beam system may be obtained by

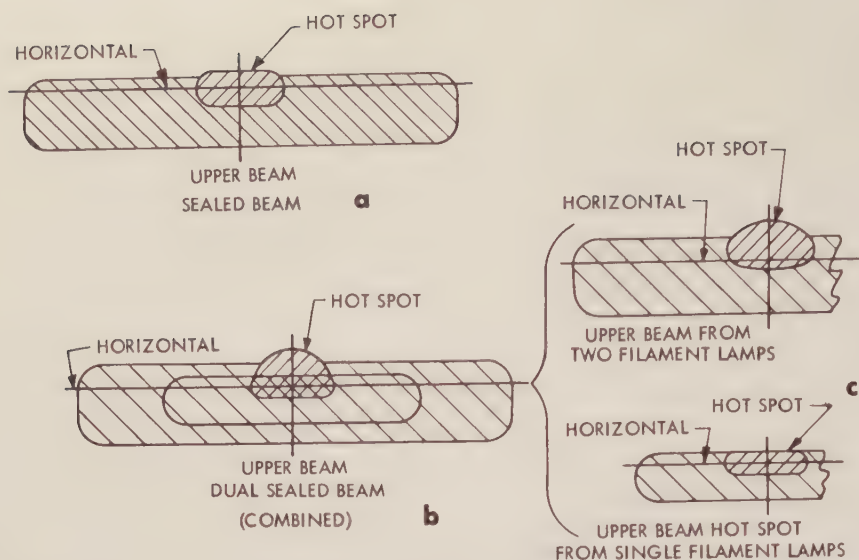


Fig. 5—The above diagrams show representations of upper beams for comparison between the single Sealed Beam (a) and the new Dual Sealed Beam (b) systems. The hot spot, or high intensity area, from the single filament lamp in the Dual Sealed Beam system is shallower and less likely to bob up and down on the road. More light is provided at the higher levels to show the way up hills and over rolling roads. The total upper beam in the Dual Sealed Beam system is a combination of light patterns from both lamps (c).

a comparison of its beam patterns with those of the single Sealed Beam (Fig. 5). For identification, *Dual Sealed Beam* denotes the new 1958 four-lamp system and *Sealed Beam* denotes the former two-lamp system. The upper beams from both systems are similar except that in the new upper beam there is more light everywhere on the road due to an increase from 100 watts to 150 watts. However, both systems have the same 75,000 maximum candlepower limit, as this is a legal limit written into many state laws.

The most radical change in beam pattern is in the lower beam (Fig. 6). In the new Dual Sealed Beam system the filament is at focus, the lens is designed specifically for the lower beam, and the wattage is increased from 80 watts to 100 watts. There is more overall light due to the added wattage. The glare, however, is not increased due to a better control of light.

To minimize glare, industry ground rules include a restriction against the use of asymmetric-right flutes in the two-filament lamp. Any asymmetric, or non-symmetrical, flute has one side thicker than the other (Fig. 7). This results in a draft angle between flutes. The draft angle and adjoining radii cause stray light to be projected in the opposite direction from the design light. Consequently, asymmetric-right flutes cause stray light to be directed to the left. This causes glare. For appearance reasons, the axis of the headlamp should be pointed straight ahead of the car. To direct the high intensity portion of the beam to the right side of the road without using asymmetric-right flutes, the axis of the reflector is tilted to the right with reference to the lamp face.

In a similar manner, down-bending prisms cause upward glare between rows of lens flutes. This has been avoided in



Fig. 6—A comparison between lower beams of the single Sealed Beam (a) and Dual Sealed Beam (b) systems shows that the Dual Sealed Beam system has a hot spot, or high intensity area, which is shallower and puts more light near the top of the beam on the right side. More light is directed to the left of the road to aid in direct and silhouette seeing. The lower beam is aimed accurately without regard to the upper beam.

Dual Sealed Beam lamps, as well as in the improved Sealed Beam lamps, by tilting the reflector axis down with respect to the lens face.

Photometric Specifications

For many years the Society of Automotive Engineers has supported a Lighting Committee charged with developing specifications for all important automotive lighting devices. The specifications are intended to maintain a uniform high standard of performance of lighting devices made by various manufacturers. The improvement of the Dual Sealed Beam system over single Sealed Beam may be shown by a comparison of the S.A.E. photometric specifications (Tables I and II).



Fig. 7—This illustration shows the effect of asymmetric lens flutes upon light. With asymmetric-left flutes (a), stray light is refracted to the right and does not glare. With asymmetric-right flutes (b), stray light is bent to the left and into the eyes of oncoming drivers.

Dual System Has Smaller Lamps

Each lamp in the Dual Sealed Beam system has a diameter of $5\frac{3}{4}$ in. as compared with 7 in. in the single Sealed Beam system. The new lamps are hermetically sealed, similar to those in the present system.

The single filament lamps have the figure 7 molded into the upper section of

CANDLEPOWER LIMITS FOR UPPER BEAM

TEST POSITION (Degrees)	SEALED BEAM		DUAL SEALED BEAM			
	One 7-in. Lamp		One Type 1 Lamp		One Type 2 Lamp	
	MAXIMUM CANDLEPOWER	MINIMUM CANDLEPOWER	MAXIMUM CANDLEPOWER	MINIMUM CANDLEPOWER	MAXIMUM CANDLEPOWER	MINIMUM CANDLEPOWER
3U-3R and 3L		500		450		300
2U-3R and 3L		1,000		750		750
1U-3R and 3L		2,000		3,000		2,000
½D-V		20,000		18,000	*	7,000
½D-3R and 3L		10,000		12,000		3,000
½D-6R and 6L		3,250		3,000		2,000
½D-9R and 9L		1,500		2,000		1,000
½D-12R and 12L		750		750		750
2D-V		5,000		3,000		2,000
2D-9R and 9L		1,500		1,250		750
3D-V		2,500		1,500		1,000
3D-12R and 12L		750		600		400
4D-V	5,000		2,500		2,500	
Maximum	37,500					

*Combined maximum candlepower at ½D-V shall not exceed 37,500.

Table I—Basic headlamp beam characteristics are established by prescribing candlepower limits in various test positions in the beam. Test positions are the degree locations up *U* or down *D* and left *L* or right *R* from the H-V position (Fig. 4). Shown here is a comparison of test point values between upper beams of the Sealed Beam and the Dual Sealed Beam systems. The values are based on S.A.E. photometric specifications. The combined values

of the Dual Sealed Beam system are substantially higher (25 to 50 per cent) than the Sealed Beam values at the longer distance and wider angle test points. They have not been changed in the immediate foreground because it is desirable to hold the light down in this area to provide a uniformly illuminated roadbed. The only reason for minimum values here is to guard against freak light distributions.

CANDLEPOWER LIMITS FOR LOWER BEAM

TEST POSITION (Degrees)	SEALED BEAM		DUAL SEALED BEAM	
	One 7-in. Lamp		One Type 2 Lamp	
	MAXIMUM CANDLEPOWER	MINIMUM CANDLEPOWER	MAXIMUM CANDLEPOWER	MINIMUM CANDLEPOWER
1U-1L to left	500		500	
½U-1L to left	800		800	
½D-1L to left	2,000		2,000	
1½U-1R to right	1,000		1,000	
½U-1R to 3R	2,000		2,000	
½D-1R to right	10,000			
½D-2R			10,000	6,000
½D-1R, or 2R, or 3R		1,000		
1D-6L				1,000
1½D-1R, or 2R, or 3R		10,000		
1½D-2R				15,000
1½D-9L and 9R		750		1,000
2D-15L and 15R		500		700
4D-4R	12,500		12,500	
10U to 90U	*125		†125	

*From the normally exposed surface of the lens.

†From the normally exposed surface of the lamp.

Table II—This table shows a S.A.E. photometric specification comparison between lower beams of the Sealed Beam and the Dual Sealed Beam systems. (The significance of candlepower limits and test positions is described in Table I.) Note that the glare values have not changed, despite the fact that more light is required on the right at the higher levels and the wattage has been increased from 80 watts to 100 watts. This is made possible by the better light control caused by the at-focus filament in the Dual Sealed Beam system. The numerical values at the longer distance test points on the right

have been increased at least 50 per cent over the present S.A.E. specification. Further increase is provided by the fact that the values for the Dual Sealed Beam system are specified at 2°R instead of 1°R, or 2°R, or 3°R. The side angle test points also have been increased more than 30 per cent. It has not been feasible to increase the values at 1°D-6°L because of the danger of exceeding the glare limit at ½°D-1°L. Also, the value at 4°D-4°R has not been changed. This test point limits the amount of light in the immediate foreground on the right.

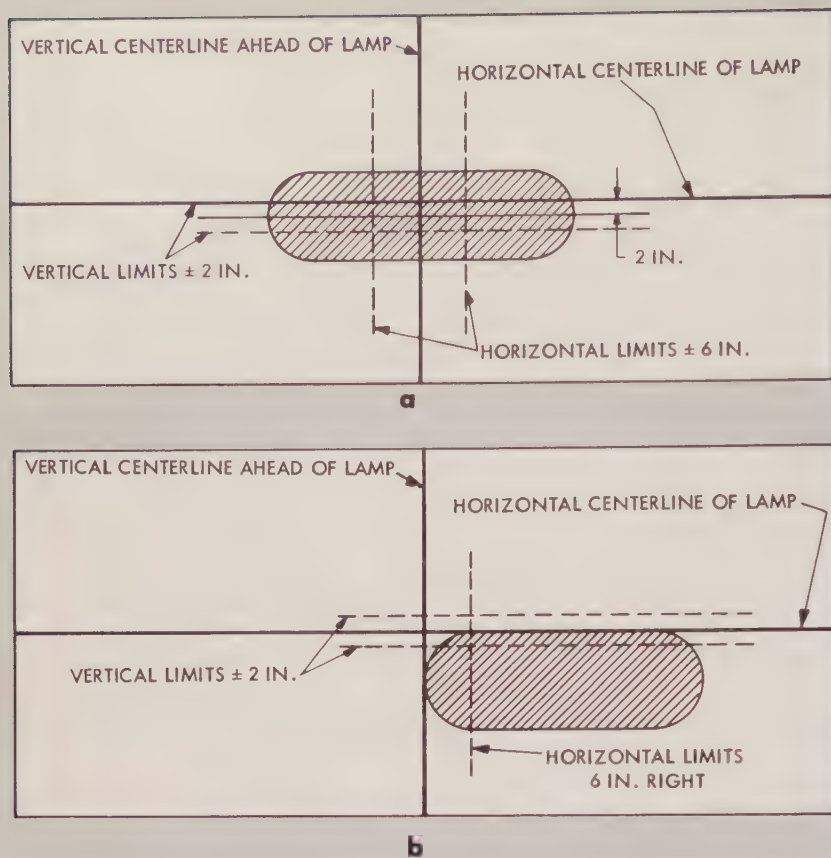


Fig. 8—The Dual Sealed Beam units can be visually aimed on a screen at 25 feet in a manner similar to that used for single Sealed Beam units. Shown here are the light patterns of the two beams superimposed on a standard visual aiming chart. The single filament, Type 1 lamp (a) provides the high intensity portion of the upper beam and is aimed so that the center of this high intensity zone is 2 in. below the level of the lamp center, with a tolerance of plus or minus 2 in. vertically and 6 in. horizontally. The two filament, Type 2 lamp (b) is aimed with the lower beam filament lighted. In this case, the lamp is aimed so that the top of the high intensity zone of the lower beam is at the level of the lamp center, within plus or minus 2 in. vertically. The left edge of the high intensity zone is aimed straight ahead of the center of the lamp with a tolerance of 6 in. to the right of this center.

the lens. The two-filament lamps have the figure 2 molded in the lens. Both lamps are designed with locating lugs molded into the back of the reflector at the seating plane. The locating lugs are so arranged that the *Type 1* and *Type 2* lamps cannot be interchanged and cannot be mounted in any position except "top up." Lamps made by various manufacturers are interchangeable and switching between the upper and lower beams remains the same as for the single Sealed Beam headlighting system.

Dual Headlamps Are Easily Aimed

An important factor leading to the development of the new Dual Sealed Beam system was the use of a mechanical means for aiming a beam (Fig. 1) with an asymmetrical lighting pattern, such as that required for the passing beam.

Lamps with either an asymmetric (passing beam) or symmetric (driving beam) lighting pattern can now be correctly aimed in broad daylight in a space slightly larger than that required for the car. The mechanical aiming device is accurate, inexpensive, and simple to operate.

The Dual Sealed Beam system, like the single Sealed Beam system, also can be visually aimed (Fig. 8). The lamps may be aimed on a screen at 25 ft in a semi-darkened room with the vehicle unloaded. The usual preparations for aiming are required, such as checking tire pressure, floor flatness, and screen calibration and alignment.

Dual Sealed Beam System Offers Many Advantages

The important advantages of the dual headlighting system are as follows:

- Better control of light resulting from the location of the primary upper and lower beam filaments at the focal point of the reflectors
- Better control of light resulting from lenses optically designed for each beam
- Greater lower beam seeing distance on the right-hand side of the road
- Improved upper beam lighting because of higher total wattage used to provide better general illumination on the road surface and road sides
- Easy identification of the upper beam for law enforcement purposes because all four lamps are lighted
- New system compatible in every manner with the existing Sealed Beam system
- Dual system provides lighting engineers with a new approach to headlamp design and offers greater latitude for further improvement in the future
- The dual headlighting system increases greatly the styling possibilities for automobiles, because the four lamps may be located in a variety of arrangements within ground rules agreed upon by the industry and state governments.

It is the intention of the automobile and lamp manufacturers to continue the cooperative study of new developments made possible by the new Dual Sealed Beam system. In the meantime, the following point should be emphasized:

The maximum benefits offered by both the single Sealed Beam system and the Dual Sealed Beam system are derived only if they are correctly aimed and periodically checked to maintain the proper headlamp aim.

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Electronic Control System Provides Indoor Proving Grounds for Transmissions

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Division

While authentic automobile performance data can be compiled on the road, laboratory testing has become very important because of its ease and economy. With an eye toward close duplication of road conditions in the laboratory, engineers in the Instrumentation Group of the Chevrolet Engineering Laboratory have designed and built a new dynamometer control system, called the *Electronic Proving Grounds*. The system is centered around a programmer which electronically schedules test conditions determined previously at the GM Proving Grounds. Another important component of the control system is an electronic vibration cut-off device. This device senses impending failure in test pieces and shuts down the test, preventing severe damage to the test piece and permitting accurate inspection of faults. The new dynamometer control system has the advantage of providing close control over conditions which simulate actual proving grounds tests.

FINAL engineering acceptance of overall automobile performance must be determined during closely simulated service conditions. This, in effect, means actual road testing which can be conducted at such facilities as the GM Proving Grounds. However, in the field of testing components such as the engine, transmission, suspension, and chassis, laboratory tests are indispensable. Obviously, the closer laboratory testing duplicates service conditions, the more valuable the test data become. With the aim of closely duplicating actual GM Proving Grounds transmission test conditions in the laboratory, the Instrumentation Group of the Chevrolet Engineering Laboratory designed and built a new dynamometer control system.

The control system, called the *Electronic Proving Grounds*, is set up as a transmission test in the dynamometer room. The system consists of a programmer, or cycling device, an electronic servo control on the throttle, a transmission range control, a vibration sensing device, and a vibration cut-off, or safety, device (Fig. 1).

Programmer is the Heart of the System

The programmer directly controls engine throttle angle and dynamometer load which, in turn, indirectly control engine input torque and speed to the transmission and the dynamometer absorbing torque and speed from the transmission (Fig. 2). Rotating weights simulating car inertia are added to absorb acceleration torque. An electric brake

provides assurance that these rotating weights are stationary before a shift to reverse is made. This is necessary since an eddy current dynamometer is used.¹

The basic idea of the programmer is quite conventional (Fig. 3). A master timer operates a micro-switch through small pins on a drum. This micro-switch then operates a stepping switch, which advances one position each time a pin contacts the micro-switch. There are five parallel control contacts at each position, and, when the relay closes, the step switch advances one notch and selects the pre-set throttle setting, dynamometer load, and other control functions.

Any change in the control requirements as the test schedule progresses is known as an *event*. Each event has its own position on the stepping switch so that the total number of events in the schedule determines the number of positions required. The programmer has provision for 50 events with five available control contacts at each position. At present, only 30 of the available events are being used in the transmission test.

The programmer may be used on either automatic or manual control. Manual control of events is obtained through an ordinary telephone dial, and is used principally to set up the original schedule on the programmer from information obtained on actual road tests at the GM Proving Grounds.

In its present usage the programmer performs the following main functions:

- Controls the engine throttle angle through a direct-coupled servo motor with feedback
- Controls the dynamometer load at the output shaft of the transmission by tapping into the present dynamometer control system
- Selects the proper transmission range (drive, grade retard, or reverse)
- Selects a predetermined electric brake, either in an *on* or *off* position, depending upon the point in the schedule
- Provides full safety with interlocks to prevent operation when the transmission oil temperature, pressure, or vibration are not in the proper range.

The input settings, that is, the proper settings for the potentiometers serving as the reference voltages for throttle angle, dynamometer load, and the time at the various speeds and accelerations, are obtained from actual Proving Grounds data. Either visual observations or oscillographic recordings of these factors are made, after which the data are reduced and tabulated on a master data sheet. With the data sheet the operator sets up the program on the programmer. First, the master timer pins are installed according to the Proving Ground timing data. Then, using manual control, the first event is dialed in. Time for the first event during set up is controlled by a timing device which is separate from the master timer. If the first event, for example, is a zero to 50 mph acceleration at wide open throttle in 10 seconds, the operator sets 10 seconds on the adjustable

timer and dials the first event. The throttle angle control is then adjusted for wide open throttle. This sets the potentiometer for wide open throttle on the servo system. By repeatedly going through the first event, the operator will adjust the dynamometer load potentiometer so that at the end of 10 seconds the vehicle velocity indicator reads 50 mph. It usually requires three or four attempts to bring the potentiometer reference voltage

adjustment to exactly the load required to meet the prescribed conditions.

The operator then proceeds to the second event and, in turn, through all 30 events until the load and throttle angles are set at the dictated conditions. The programmer is then placed on automatic control, and it continuously cycles the engine transmission through the test schedule. The programmer is shut off only by a malfunction of the transmission

or by the operator.

With the actual field test information as the basis for the control of transmission input and output loads, the programmer will put the engine transmission through almost exactly the same load maneuvers, including climbing hills, braking, and shifting to reverse, as the assembly went through on the actual field test schedule. The extent to which the actual and electronic conditions are

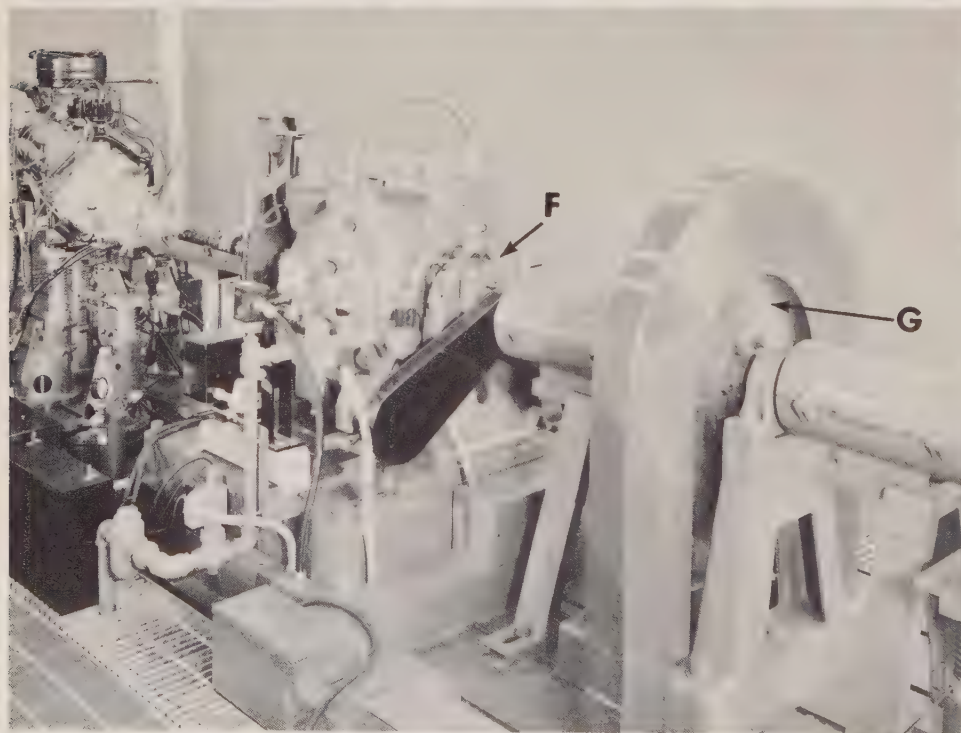
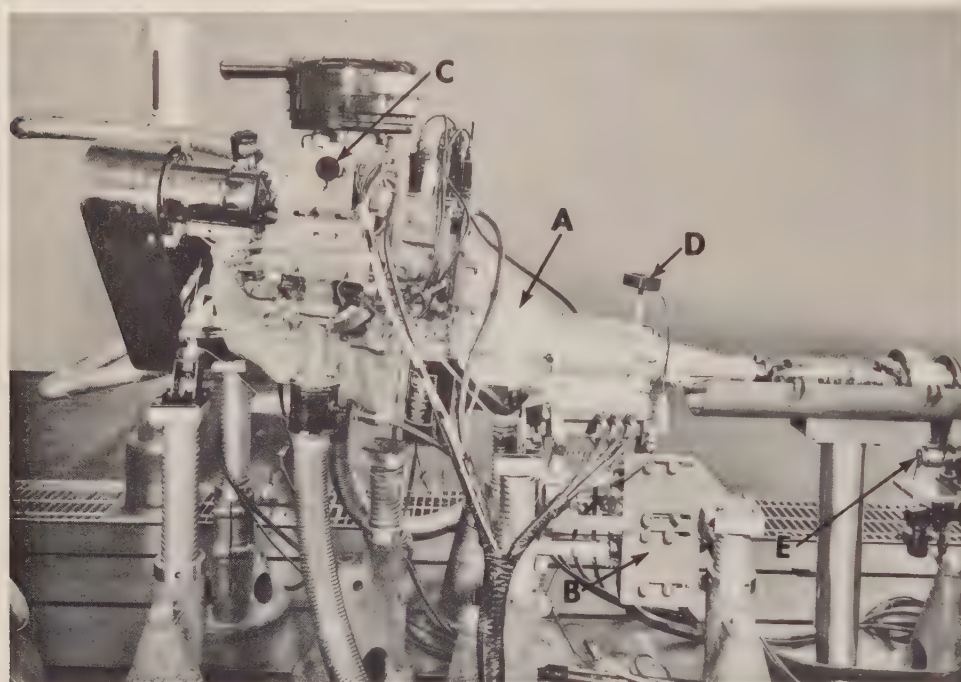


Fig. 1—Some of the significant components of the Electronic Proving Grounds, shown in this laboratory transmission test set up (top) are: the transmission undergoing the test *A*; the transmission range control *B*; the electronic servo control on the throttle *C*; the vibrating transducer of the cut-off device *D*; and the instantaneous load disconnect *E*. Another view of the transmission test set up (bottom) shows the dynamometer *F* and inertia weights *G* which simulate vehicle mass.

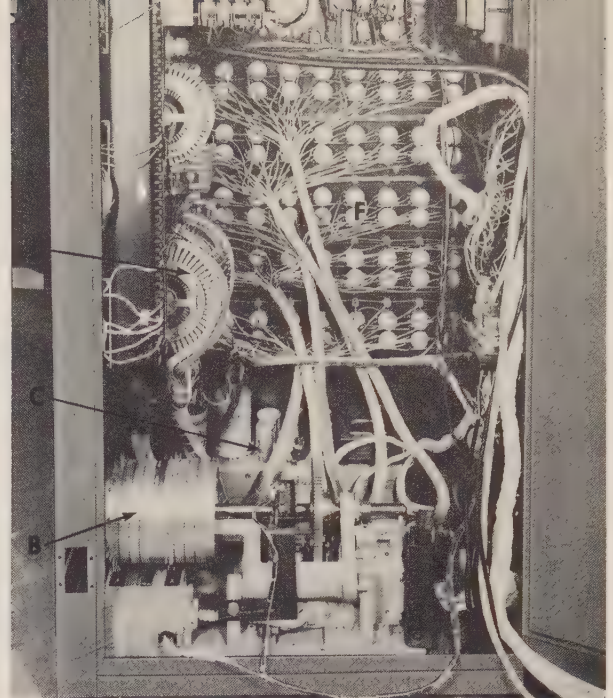


Fig. 2—This front view of the programmer (left) includes the display panel *A*, which was constructed primarily for exhibition purposes. When the dynamometer load is adjusted to bring the vehicle to conditions dictated by Proving Grounds data, lights on the panel indicate the position where the data were collected. The vehicle would be at this point if an actual road test

was being conducted. The programmer (right) is the heart of the electronic control system and controls the load conditions, throttle adjustment, transmission range, and cycling of the test. Some basic components of the programmer are: the master timer *B*; the throttle servo amplifier *C*; stepping switches *D*; vibration cut-off electronics *E*; and reference potentiometers *F*.

duplicated has been shown by the excellent correlation between results from the two tests.

Safety Features Are Built-In

Safety interlocks are provided between the transmission and the programmer so that if pressures, temperatures, or vibra-

tions in the transmission are not in the proper range, the programmer will automatically keep the engine at idle and remove all electrical power from the dynamometer and engine. For example, consider the case if the schedule requires a shift to reverse but, due to malfunction, transmission pressures are not of proper

value to accomplish this shift. The programmer will sense this, keep the engine at idle, and, after a certain time, will remove all power from the system. A light on the control panel will indicate at which event failure occurred.

Vibration Cut-Off Device Foresees Failures, Stops Test

An important feature of the electronic control system is a built-in electronic vibration cut-off, a vibration safety device used to quickly shut down the test in case of component failure. This device consists of a vibration transducer and an amplifier and thyatron controlled relay circuit. Although the amplifier and relay circuit are conventional, it was found that for this application the transducer should be an accelerometer or shock sensing device (Fig. 4).

This kind of vibration cut-off device was selected because the vibration level felt by the transmission case varies considerably during the test schedule. The amplifier gain is adjusted to ignore these normal variations, but it operates the vibration cut-off relay only on the sharp click of fracture type failures.

A failure produced by wear, which might slowly increase the vibration level, can be detected by the operator during periodic checks of transmission perform-

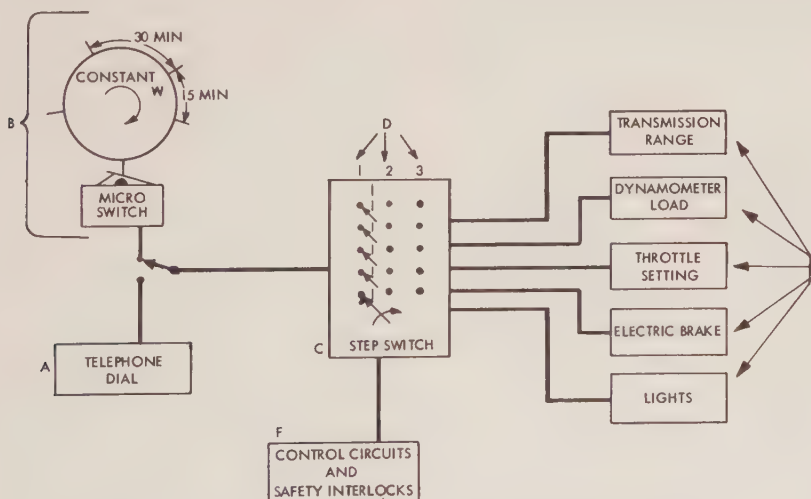


Fig. 3—The basic idea of the programmer is illustrated in this diagram. The programmer can be controlled either manually or automatically. Manual control is achieved with an ordinary telephone dial *A*. Automatic control is accomplished by a master timer *B*, which consists of a micro switch that is actuated by small pins on a rotating drum. The control unit operates a step switch *C*, which advances one position *D* with every timer pulse (each time a pin contacts the micro switch). There are five parallel control contacts at each position *E*. These five contacts select the pre-throttle setting, dynamometer load, transmission shift position, electric brake, and accessory lights. Also acting through the step switch are the control circuits and safety interlocks *F*, which shut down the test in case of malfunctioning test components.

ance during the test. In this case, the operator has enough time to shut down the test before considerable damage occurs. In the case of a sudden failure, however, such as partial or complete gear tooth failure, the operator has no way to foresee the fault. By the time he has become aware of it, much damage has usually occurred. The vibration cut-off has solved this dilemma. When a sudden failure occurs, the sharp click or sharp acceleration is sensed by the vibration cut-off transducer, which operates a relay through an amplifier. The relay simultaneously removes engine ignition voltage and operates an air solenoid to uncouple the dynamometer inertia from the output of the transmission. This action instantly frees the transmission from all loads.

Rapid discovery of failures and quick cessation of the test prevents considerable damage to the test piece (Fig. 5). Not only is the inspection of weak design points made more precise, but nearby components are preserved from destruction. The latter is extremely important when testing expensive prototypes.

Since there is no concern about continuously monitoring the overall vibration level, a simple scheme for setting the sensitivity level of the cut-off device has been devised. First, the cut-off device is transferred from its normal circuit to a simple tell-tale light circuit. The engine is then brought to an average operating condition to produce a general level of vibration on the transmission case. Next, the case is tapped with a light metallic mallet to simulate a sudden failure inside the transmission. The rap is similar to the click which occurs when a gear tooth is approaching failure. Using the tell-tale light, the cut-off device is adjusted to function at the vibration level of the mallet tap. When returned to its normal circuit, the cut-off device operates the shut-off control when the "mallet tap" vibration level is reached by the transmission.

Conclusion

The electronic control system has several advantages which the actual road test lacks. Some of these advantages are: (a) close control over throttle angle and loads, which eliminates the variability of drivers and vehicles; (b) elimination of the effects of inclement weather; (c) elimination of transmission test delays because of failure of other vehicle com-

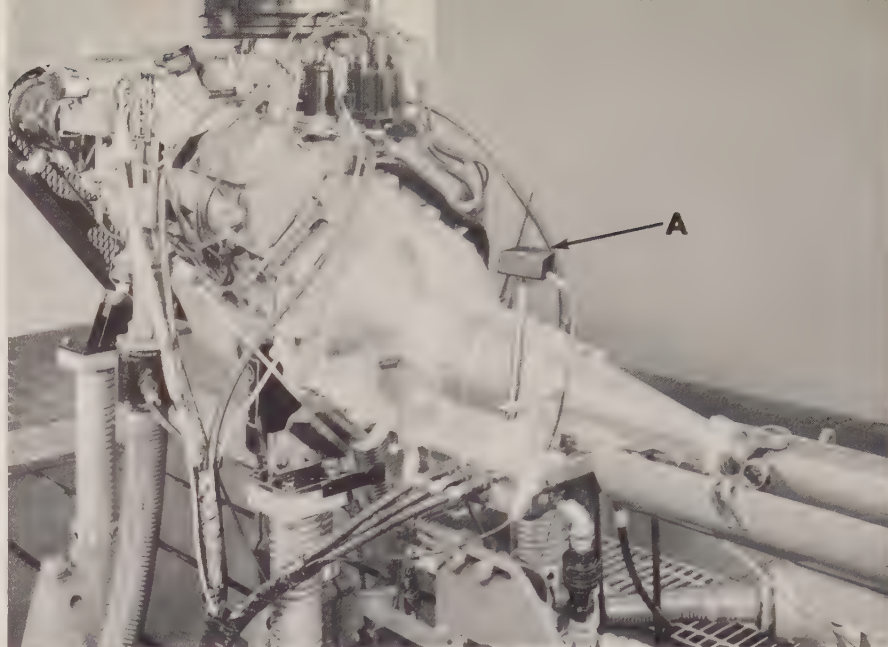


Fig. 4—The vibration transducer *A* is the sensing apparatus for the vibration cut-off device. The transducer is a shock-sensing device, which, when it perceives extreme variations in the vibration level of the transmission, actuates a relay which removes all loads from the transmission.

ponents; (d) pinpointing and close inspection of broken parts, utilizing the automatic shut down devices; (e) ease in introduction of loads which exceed those in the normal Proving Grounds schedule to accelerate the test; (f) cycling of engine accessories under simulated conditions, and, since the parts are very accessible in dynamometer testing, failures may be changed with a minimum loss of time; and (g) practically any kind of programming or scheduling may be obtained through the use of this flexible control system.

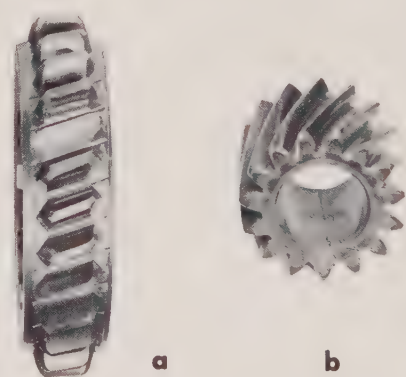


Fig. 5—These two gear failures illustrate the benefits of the vibration cut-off device. Sudden failures, such as a broken gear tooth (a) or a fracture (b), are detected by the cut-off device which instantly shuts down the test. This quick action prevents the complete destruction of components which failed under exaggerated load conditions, and permits accurate inspection of the faults.

The electronic control system also has its limitations. Since the effect of inclement weather is eliminated in the laboratory, any tests which depend on the weather cannot be programmed indoors. Furthermore, components under test in the laboratory do not feel all of the vibrations that occur in actual road testing.

The success of the electric control system is corroborated by the adaption of similar equipment to other testing schedules. For example, four simplified versions of this programmer are being used to cycle truck engines through durability tests. Although the actual road test remains the most conclusive method to test automobiles, the electronic control system has firmly entrenched itself in the field of automotive component testing.

Acknowledgment

The authors acknowledge the work of L. W. Lepkowski of Chevrolet-Cleveland in the field of vibration cut-off devices, and the work of technicians R. J. Blaszak and N. R. Clark in the layout and construction of the programmer.

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An Analog Method for Finding the Real and Complex Roots of Higher Order Polynomial Equations

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The solution of polynomial equations is a requirement that occurs in various product design problems in industry. These equations appear frequently, for example, in stability studies of control systems for aircraft jet engines. At Allison Division engineers were interested in finding an improved method for solution of such equations. An analog method, using commercially available components, was therefore developed. Using this method, it is possible to determine all of the real and complex roots of any polynomial equation to any desired degree of accuracy. The multiplicity of any root and the number of roots in any given region also may be determined. The equation may have either real or complex coefficients. This analog method offers a saving in solution time for polynomial equations. Twelfth order equations, for example, can be solved in 30 minutes as compared to about three days using hand methods.

Solution time for 12th
order equations reduced
from 3 days to 30 min.

IN many physical and mathematical investigations it often becomes necessary to find all of the real and complex roots of higher order polynomial equations. In stability studies of control systems for Allison jet engines these equations occur regularly. At present, there are many numerical procedures developed for solving these equations, but all are extremely laborious, especially when complex roots are to be located. Trouble in solving certain equations using a digital computer led to an investigation of analog methods.

Theory

Consider the following polynomial:

$$f(z) = a_n z^n + a_{n-1} z^{n-1} + \dots + a_1 z + a_0 = \sum_{m=0}^n a_m z^m \quad (1)$$

where, in general, the coefficients are complex, as follows:

$$\begin{aligned} a_n &= \alpha_n + i\beta_n \\ a_{n-1} &= \alpha_{n-1} + i\beta_{n-1} \\ &\vdots \\ a_0 &= \alpha_0 + i\beta_0. \end{aligned} \quad (2)$$

Let

$$z = R(\cos \Theta + i \sin \Theta) \quad (3)$$

where

$$|z| = R.$$

This is the general trigonometric form of the roots of the equation $f(z) = 0$.

Substituting equation (3) into equation (1), $f(z)$ becomes

$$\begin{aligned} f(z) &= f(R, \Theta) \\ &= \sum_{m=0}^n a_m R^m (\cos \Theta + i \sin \Theta)^m \quad (4) \end{aligned}$$

Applying DeMoivre's Theorem, equation (4) becomes

$$\begin{aligned} f(R, \Theta) &= \sum_{m=0}^n a_m R^m (\cos m\Theta \\ &\quad + i \sin m\Theta). \end{aligned} \quad (5)$$

Substituting equations (2) into equation (5) gives the following:

$$\begin{aligned} f(R, \Theta) &= \sum_{m=0}^n (\alpha_m + i\beta_m) R^m (\cos m\Theta \\ &\quad + i \sin m\Theta) = X + iY \end{aligned} \quad (6)$$

where

$$\begin{aligned} X &= \sum_{m=0}^n R^m (\alpha_m \cos m\Theta - \beta_m \sin m\Theta) \\ Y &= \sum_{m=0}^n R^m (\beta_m \cos m\Theta + \alpha_m \sin m\Theta). \end{aligned}$$

This polynomial is now in a convenient form for generation by analog methods. A convenient method for this generation will be described under the section *Establishing the Circuit*.

Equation (6) also can be written in the polar form as follows:

$$f(z) = f(R, \Theta) = Z e^{i\Phi} \quad (7)$$

where

$$\begin{aligned} Z &= +\sqrt{X^2 + Y^2} \\ \phi &= \tan^{-1} \left(\frac{Y}{X} \right). \end{aligned}$$

Taking natural logs, equation (7) becomes

$$\ln f(z) = \ln Z + i\phi. \quad (8)$$

Differentiating:

$$\frac{f'(z)}{f(z)} dz = \frac{1}{Z} dZ + i d\phi. \quad (9)$$

Therefore,

$$\oint_C \frac{f'(z)}{f(z)} dz = \oint_C \frac{1}{Z} dZ + \oint_C i d\phi. \quad (10)$$

Making the restriction that $Z \neq 0$ on the closed path C , the function $1/Z$ is analytic for all Z^1 . From Cauchy's integral theorem, therefore, the following is obtained:

$$\oint_C \frac{1}{Z} dZ = 0. \quad (11)$$

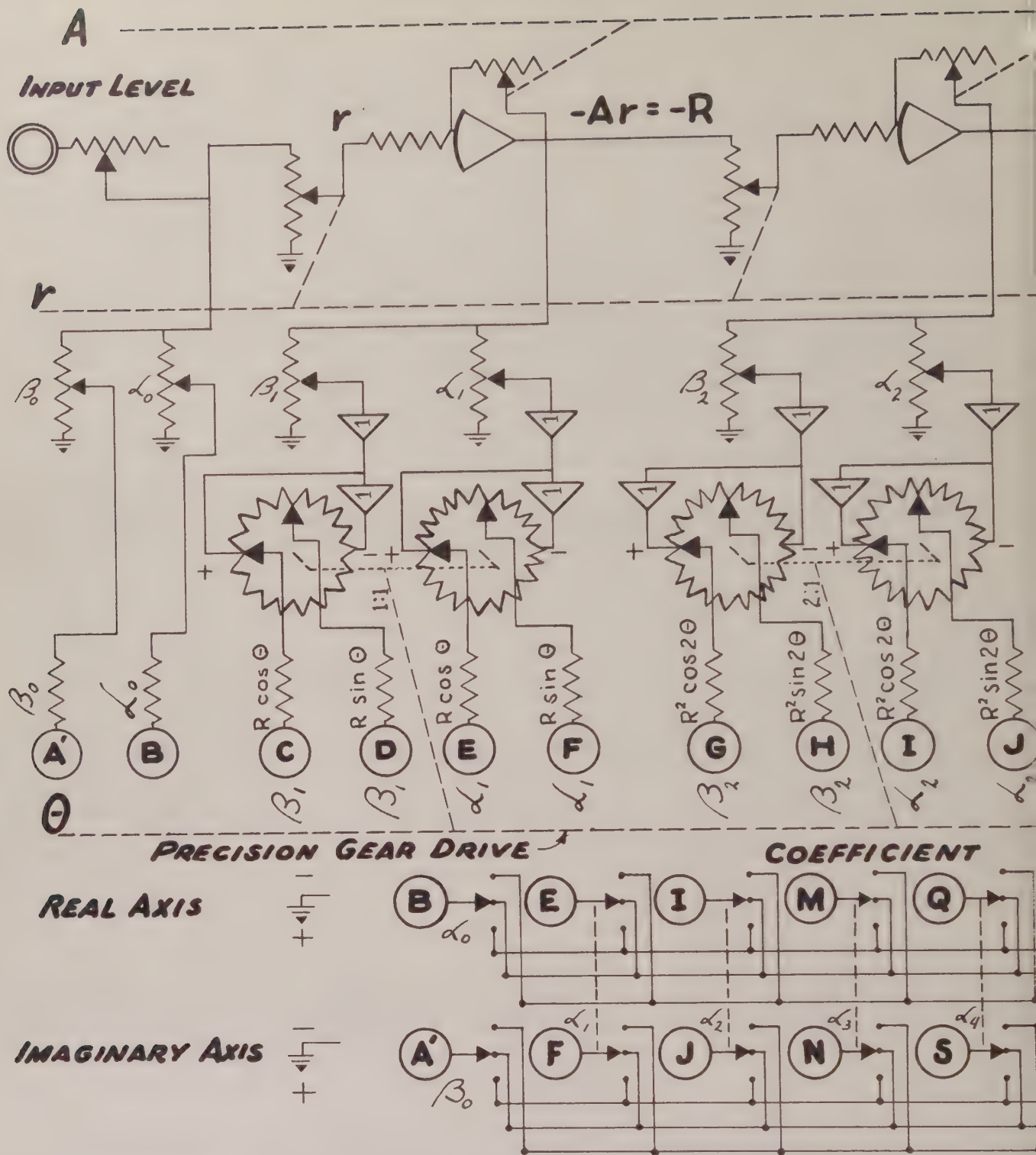
Hence, equation (10) becomes:

$$\oint_C \frac{f'(z)}{f(z)} dz = \oint_C i d\phi. \quad (12)$$

From the theory of complex variables, the following is obtained:

$$\frac{1}{2\pi i} \oint_C \frac{f'(u)}{f(u)} du = N_o - N_p \quad (13)$$

where $f(u)$ is analytic in domain D ; C is any simple closed path in D within which $f(u)$ is analytic except for a finite number of poles N_p ; $f(u) \neq 0$ on C ; and N_o is the number of zeros inside C , both poles and zeros being counted according to

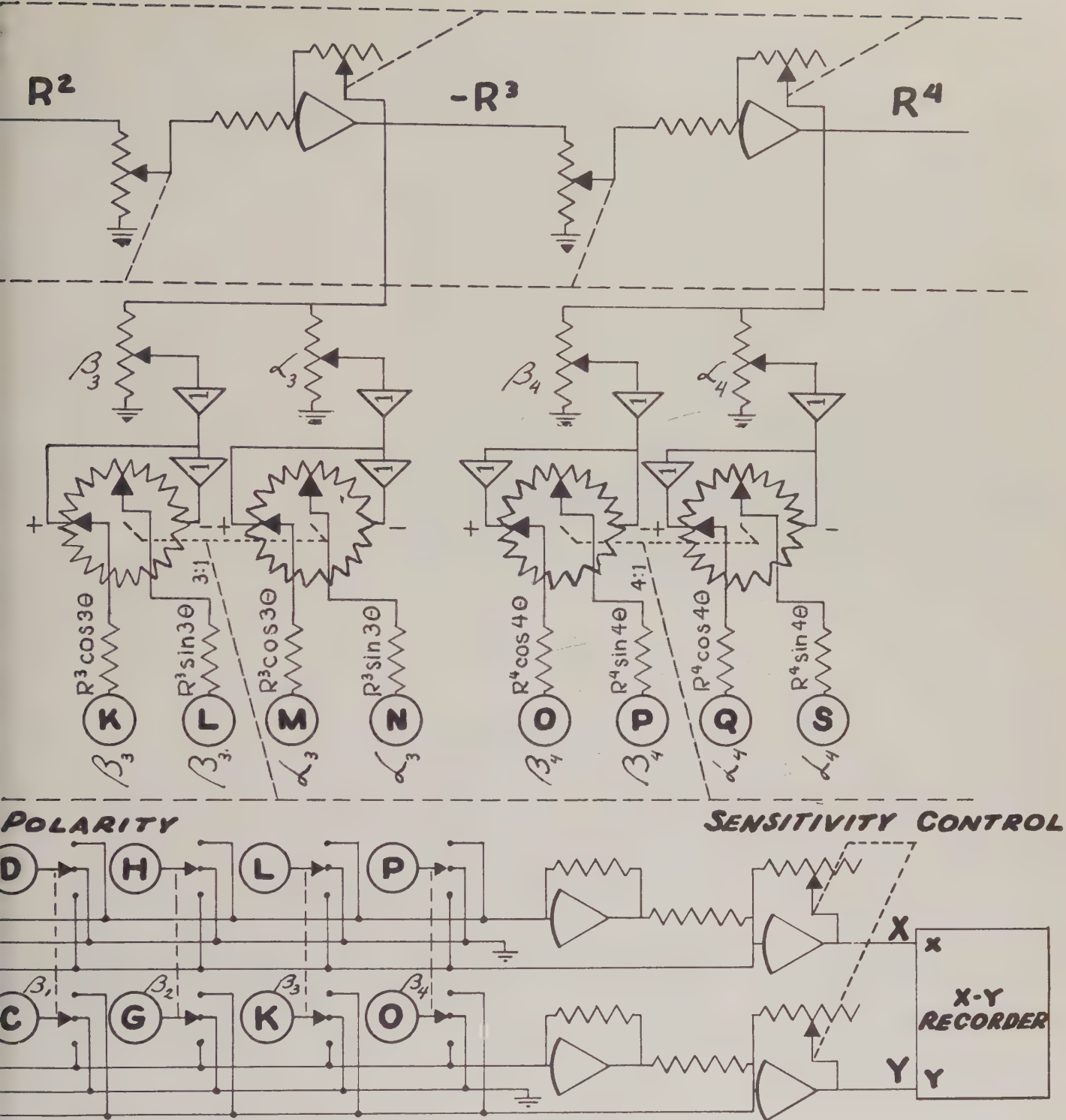


their multiplicities². Thus, since a polynomial is an analytic function having no poles

$$\frac{1}{2\pi i} \oint_C \frac{f'(u)}{f(u)} du = N_0. \quad (14)$$

Fig. 1—This is a schematic diagram of the special purpose analog computer for solving fourth order polynomial equations having either real or complex coefficients. Various powers of the radius vector are generated by the upper row of amplifiers and associated components. Coefficients are impressed by the potentiometers appearing in the second row. The row of circular drawn potentiometers impresses the angular value of the

radius vector and separates the results into real and imaginary components. The row of components labelled *Real Axis* receives and totals the real components. The row of components labelled *Imaginary Axis* receives and totals the imaginary components. The two inputs are then the magnitude of the radius vector r , and the angular value θ . The two outputs are the real and imaginary totals.



Applying this theorem, equation (12) becomes:

$$\frac{1}{2\pi i} \oint_C i d\phi = N_0$$

or

$$\frac{1}{2\pi} \oint_C d\phi = N_0. \quad (15)$$

Hence, the number of zeros enclosed in

any region bounded by the closed path C is equal to the value of the integral

$$\frac{1}{2\pi} \oint_C d\phi$$

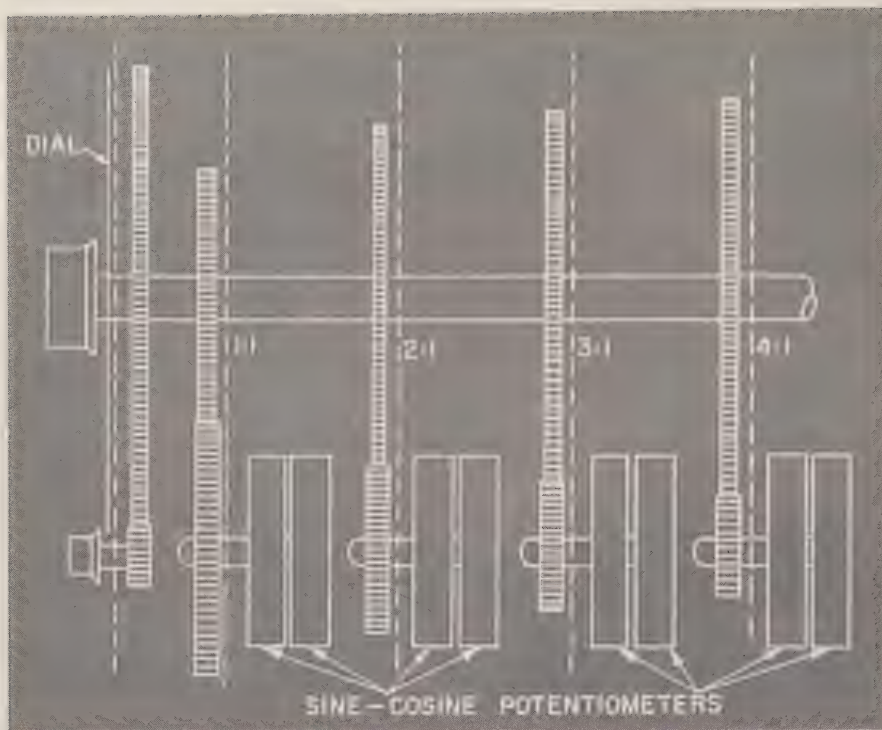


Fig. 2—This diagram represents the precision gear drive and potentiometer assembly. When the dial is set to angle Θ , the gear ratios cause the potentiometers to give outputs proportional to $\sin \Theta$ and $\cos \Theta$, $\sin 2\Theta$ and $\cos 2\Theta$, $\sin 3\Theta$ and $\cos 3\Theta$, and $\sin 4\Theta$ and $\cos 4\Theta$.

around that region, provided that this path passes through no zeros.

This integration also can be performed by analog methods. From equation (7)

$$f(z) = X + iY$$

it is apparent that if the complex function $f(z)$ is generated and plotted in the complex plane the number of times this plot encircles the origin, as z varies in such a way as to go around the closed path C , is the value of the following integral:

$$\frac{1}{2\pi} \oint d\phi.$$

Establishing the Circuit

As can be seen from the discussion so far, the problem reduces to one of generating and plotting $f(z)$ in the complex plane. A circuit was developed (Fig. 1) for generating the complex function $f(z)$ by independently generating its real and imaginary components, $f(z) = X + iY$, and simultaneously plotting them on an x - y recorder. It can be readily seen that this circuit also will solve the equation $f(z) = 0$, for only the values of z for which the polynomial $f(z)$ has a zero are roots of the equation $f(z) = 0$. But when $f(z) = 0$, both X and Y must independently equal zero from properties of com-

plex numbers. Hence, only when z takes on the value of a root will the output plot be at the origin.

The radius vector R is generated by ganging potentiometers and using isolation amplifiers to prevent loading errors. These isolation amplifiers are equipped with variable feedback resistors so that the value of the radius vector ($R = Ar$) can extend beyond the limits $0 \leq r \leq 1$. The variable gain A is introduced by varying the feedback resistance rather than varying the input resistor in order that the ganged potentiometers can be wound to work into a fixed load. In the diagram, the variable feedback resistors are shown by a rheostat symbol; however, in practice, it would be better to utilize precision matched resistors in a switching network.

The addition of variable gain introduces the possibility of overloading the amplifiers. To prevent this the *Input Level* control should be adjusted to reduce the value of the voltage called unity.

After the powers of the radius vector R are generated, the various values of the coefficients are impressed upon their respective powers of R by means of coefficient potentiometers. The circuitry is such that the potentiometers can be wound to work into a fixed load.

The sines and cosines of the various integral multiple angles are impressed by using single turn, continuous rotation sine-cosine potentiometers, driven by a precision gear drive (Fig. 2). The various components are then added (taking into account the polarity of all coefficients) to form the following two components:

$$X = \sum_{m=0}^n R^m (\alpha_m \cos m\Theta - \beta_m \sin m\Theta)$$

$$Y = \sum_{m=0}^n R^m (\beta_m \cos m\Theta + \alpha_m \sin m\Theta).$$

These two components are then displayed on an x - y recorder. The values of these two components can be amplified by varying the *Sensitivity Control*. This makes it possible to increase both the sharpness of the null point and, in turn, the accuracy.

Preparing the Equations

To prepare an equation for solution by this computer, the equation is divided through by some number which is equal to or greater than the largest coefficient (or constant) in the equation. If a resultant coefficient (or constant) is so small that it cannot be set easily on the computer, a substitution of the form $z = 0.1y$, or $z = 10y$ should be tried. A cursory examination of the equation will reveal which substitution is better. For accuracy it is highly desirable that all coefficients be greater than 0.01.

In the event that a substitution of this nature cannot readily be found, then the coefficients of the lower powers of z should be made large while the coefficients of the higher powers may approach zero. Since, in general, $|z| < 1$, z^n will be less than z . The error introduced, therefore, will be very small.

For the range $|z| \leq 1$, the equation as derived above is used.

For the range $|z| \geq 1$, the substitution $z = 1/x$ is made and the equation multiplied by x^n . The resulting equation may be solved in the regular manner*. ($z \geq 1 \Rightarrow x \leq 1$). When finding z from x , care must be taken to determine the correct quadrant for the angle.

For values in the neighborhood of unity, the setting of the control labeled A (Fig. 1) can be increased and the input

*An elaborate switching network could be designed to handle this inversion; however, it would be better to do this manually since an elaborate switching network would constitute a source of noise and trouble.

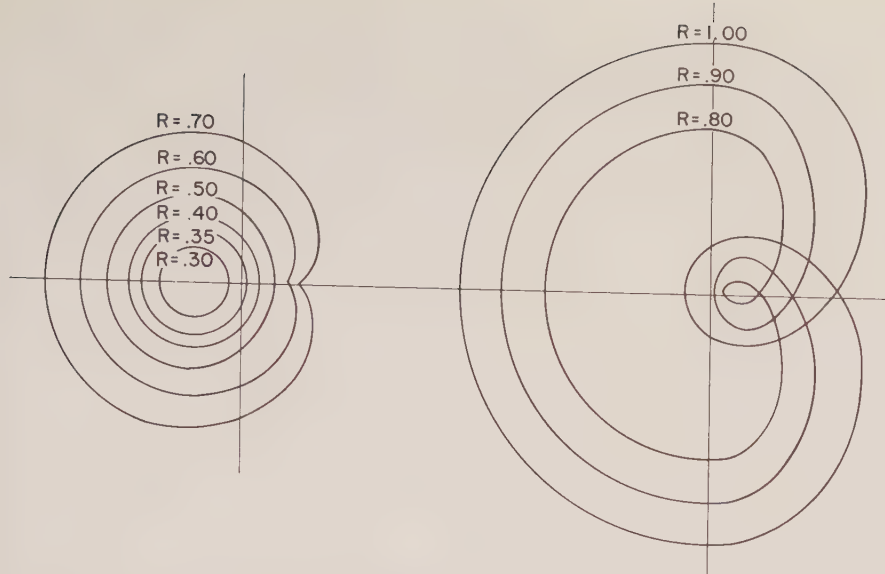


Fig. 3—The x-y recorder shows the plots for equation (20), in Table I, for Θ from 0 to π radians. The number of roots enclosed in a circular region of radius R is equal to twice the number of times the plot encloses the origin. For $R = 0.30$, no roots are enclosed. For $R = 0.35$, two roots are enclosed. For $R = 0.90$, two roots are enclosed; however, two additional roots are very close to being enclosed, as shown by the small loop. For $R = 1.00$, four roots are enclosed. These plots are for a Sensitivity Control gain of unity.

level control decreased so that no amplifiers are overloaded. The value of the radius vector R is then equal to $A\epsilon$. In normal use, the value of A should be set at unity.

It also is possible to use this computer to find roots to any degree of accuracy and to isolate roots that are closely spaced. If z is the variable and C represents the root found on the computer (where C , in general, is complex) make the substitution $z = C + \epsilon$ and perform the necessary calculations to reduce the

equation to an equation in the variable ϵ . The resulting equation can then be solved for ϵ , which is a correction factor on C . This process of successively translating the origin can be continued to give a root to any desired degree of accuracy. As an example consider the following equation:

$$z^4 + 28z^3 + 294z^2 + 1,372z + 2,400 = 0. \quad (16)$$

†For roots spaced closely together, pick C at random to be very close to these roots.

SUMMARY OF COMPUTER RESULTS

ACTUAL ROOTS	COMPUTER RESULTS	PER CENT ERROR
$z^4 + 1,024 = 0$ (19)		
$4.0 \pm 4.0i$	$3.99 \pm 3.99i$	0.25
$-4.0 \pm 4.0i$	$-3.99 \pm 3.99i$	0.25
$z^4 + 96z^2 + 1,024 = 0$ (20)		
$\pm 3.50i$	$\pm 3.41i$	2.5
$\pm 9.15i$	$\pm 9.24i$	1.0
$z^4 + 28z^3 + 294z^2 + 1,372z + 2,400 = 0$ (16)		
-6.0	-5.98	0.33
-8.0	-7.98	0.25
$-7.0 \pm 1.0i$	$-7.0 \pm 1.0i$	1.0*

*Imaginary component only.

Table I—The solution of three selected fourth-order polynomial equations (16), (19), (20) was accomplished with a general purpose analog computer to test the proposed analog method. The results indicated that the proposed circuit, which is inherently more accurate, will produce very satisfactory solutions. The first equation (19) should be easy to solve, while the third equation (16) should be difficult. For solving equation (16), a translation of the axis was made, after which the roots were located with comparatively good accuracy.

Dividing equation (16) through by 2,500 gives the following:

$$0.0004z^4 + 0.0112z^3 + 0.1176z^2 + 0.5488z + 0.9600 = 0.$$

Since all of the coefficients are not of the right order of magnitude, let $z = 10y$. The above equation then becomes:

$$4y^4 + 11.2y^3 + 11.76y^2 + 5.488y + 0.9600 = 0.$$

Dividing through by 12, the above equation reduces to:

$$0.333y^4 + 0.933y^3 + 0.980y^2 + 0.457y + 0.080 = 0 \quad (z = 10y) \quad (17)$$

which is then set on the computer for $y \leq 1$.

If $|y| \geq 1$, let $y = 1/x$. This then becomes

$$0.080x^4 + 0.457x^3 + 0.980x^2 + 0.933x + 0.333 = 0 \quad (z = 10/x)$$

which is then set on the computer for $|y| \geq 1$.

When equation (17) is set on the computer it is found that all of the roots lie close to the negative real axis and between $0.5 \leq y \leq 0.9$. Thus, a point is picked at random in this region and the process of isolating these roots begins.

Translating the origin to $z' = -7$, equation (16) becomes $z'^4 - 1 = 0$. The roots of this equation are found on the computer and they are then translated back to the original equation—that is, $z = -7 + z'$.

Circuit Theory Checked on a General Purpose Analog Computer

In order to test this method, an elaborate setup was made on a general purpose analog computer. Since no precision gear drive and no ganged potentiometers were available, this setup used 29 amplifiers and 19 multipliers for a fourth degree equation with real coefficients only. The multiple angle trigonometric functions were generated by using multiple angle formulae.

This method was tested on the general purpose computer by solving three, fourth-order polynomial equations and the results were summarized (Table I). The plots on the x-y recorder for one of the equations show the extreme sensitivity of this method (Fig. 3). The relatively small per cent error for the elaborate setup used indicates that the special purpose computer described in

this paper (using no multipliers and only 22 amplifiers for fourth degree equations with *complex* coefficients) should yield results that are accurate to two significant figures with an estimate on the third. For further accuracy, the technique of successively translating the origin can be used.

Conclusion

This analog method provides a successful way to generate polynomials, to determine the number of roots in any given region, to determine the multiplicity of roots, and to locate the roots to any desired degree of accuracy of any degree equation with either real or complex coefficients. All of the components utilized are commercially available. Probable time for solving a twelfth order equation is 30 minutes as compared to three days for hand methods.

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Radioisotope Measuring Gage Applied to the Production of Storage Battery Separators

DURING the past few years the radioactive isotope has had an ever-broadening application by industry to research, engineering development, manufacturing processing, and quality control. A recent application of this increasingly important and versatile industrial tool was made by Delco-Remy Division for the processing of microporous rubber separators for storage batteries.

A difficult problem in the processing of rubber separators for storage batteries is obtaining accurate thickness measurements of the rapidly moving rubber sheet leaving the calender rolls. (In a later operation the sheet is cut into the proper size for the separators). The problem stems from the fact that spongy, freshly calendered rubber cannot be measured accurately by standard measuring devices. The usual practice is to measure the selvage edge of the uncured rubber with a micrometer as the sheet comes from the calendering mill. Measurements of the spongy material made by experienced operators are at best an "educated guess," whose accuracy cannot be closely checked until the rubber

completes the curing cycle several hours later. This time delay makes it difficult to prevent the processing of some material outside production tolerances.

Operator skill and judgment are relied upon for measuring the thickness of the rubber sheet and for making the necessary machine adjustments required to hold the product within tolerance. To avoid running scrap the operators tend to hold to the high side of the thickness specifications, since material falling outside the low limit cannot be salvaged. Operating on the high side eliminates scrap. This procedure, however, gives a relatively low yield in square inches of rubber separator per pound of raw material.

Nuclear Measuring Device Provides Desired Accuracy

Delco-Remy engineers felt that if the measuring process could be brought under complete control, the thickness specification tolerances could be tightened and substantial material savings affected. In addition, the thinner rubber separators would offer less electrical

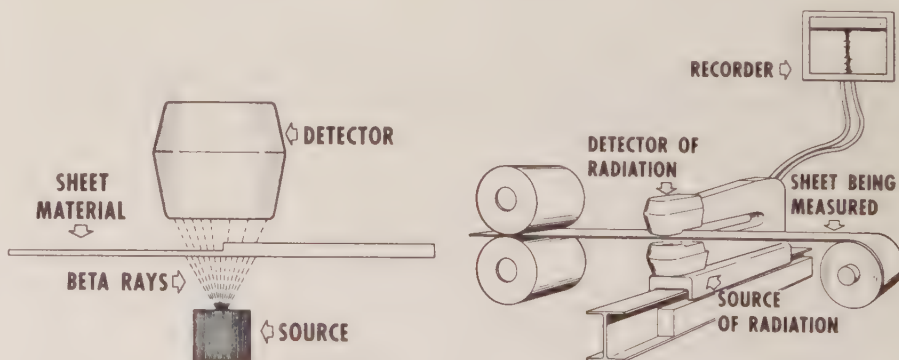


Fig. 1—These diagrammatic sketches illustrate the operating principles of the radioisotope measuring gage. The source of radiation (a) is a hermetically sealed capsule containing a radioactive substance. This substance provides a constant source of high-speed beta rays. The detector unit, which acts as a specialized geiger counter, is filled with an inert gas. As the detector unit is bombarded by the beta rays passing through the sheet material, some of the gas is ionized. This sets up electrical voltages which activate the recorder and an automatic calender mill control monitor. When the control monitor indicates a thickness above or below a specified limit, information is fed to an electro-mechanical system. This system automatically adjusts the calender roll settings to bring the separator thickness back to the specification median. The number of beta rays penetrating the sheet material is in proportion to the mass per unit area of the material. Thickness of the sheet is recorded instantaneously in thousandths of an inch on the recorder chart. The complete radioisotope gage, which has the appearance of an elongated C clamp (b), has the detector unit placed about two inches above the source of radiation.

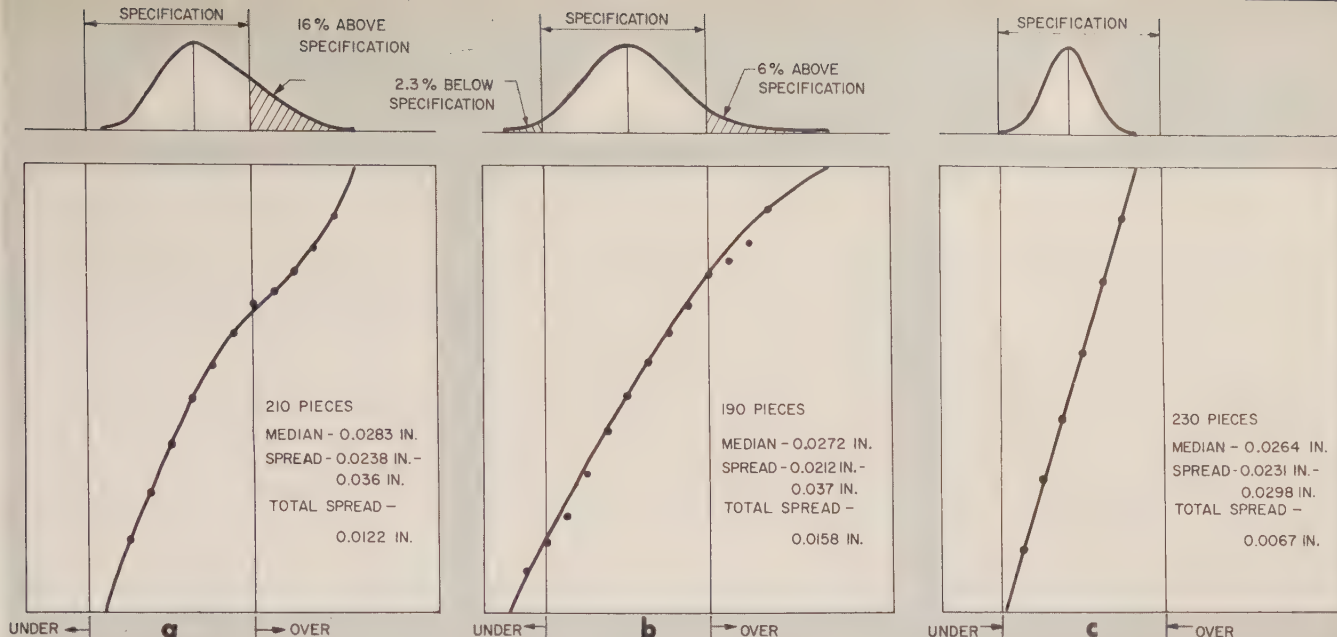


Fig. 2—Shown here are samples of quality control records made before and after the installation of the radioisotope gage. The records indicate that typical runs made before the gage was installed (a) and (b) were well under control, but considerable day to day variation occurred. The thickness of the rubber sheet varied toward the high end of the specification limit. A quality control record made a few days after the gage was installed (c) indicates that the electro-mechanical control system, combined with radioisotope gaging, has stabilized the process so that all samples are very close to the specification media. The result is a considerable material saving.

resistance and result in a more responsive battery giving higher terminal voltages.

The standard commercially available measuring devices were not capable of providing the complete control desired. A measuring device which would satisfy

the processing requirements, and which had proven itself in similar industrial applications, was the radioisotope gage (Fig. 1). This gage was investigated, the manufacturer contacted, and plans completed for its installation.

Separator Quality Improved

Soon after the radioisotope gage was installed an improvement in thickness uniformity of the separators was realized when a comparison was made of quality control records before and after installation (Fig. 2). Use of the nuclear measuring device made it possible to hold tolerances previously unobtainable. Thickness measurements of 1/10,000th of an inch could be read with an error of less than one per cent.

The radioisotope gage now makes it possible to inspect, measure, and control the thickness of the rubber sheet as soon as it leaves the calender rolls (Fig. 3).

Summary

The application of the radioisotope gage at Delco-Remy has made possible the production of more rubber separators per pound of material and has greatly improved quality. Use of this nuclear measuring instrument has taken the guesswork out of the separator manufacturing process and has made possible a closer control over all phases of rubber calendering.

The radioisotope gage has proven to be a useful and valuable production tool. Thinner microporous rubber separators having greater uniformity in thickness are now being processed. The greater uniformity in thickness has allowed separator resistance to be lowered an average of 10 per cent. This lower electrical resistance in the separator makes possible a storage battery with significantly higher terminal voltage and increased ability to crank the engine.

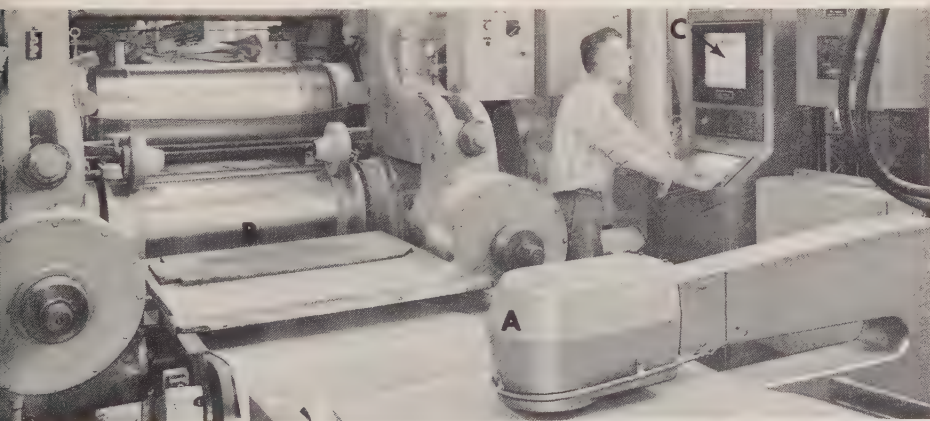


Fig. 3—The radioisotope measuring gage has scanning units resembling elongated C clamps which ride on pneumatically actuated, pedestal-mounted traversing systems. The radiation source (not shown) is mounted on the bottom jaw of the clamp. The detector unit A is mounted on the upper jaw. The measuring gage is located adjacent to the calendering rolls B and arranged so that the rubber sheet leaving the rolls passes between the radiation source and the detector unit.

Electro-mechanical controls activated by the continuous readings of the radioisotope gage automatically adjust the calender mill rolls to produce separator material of unusual uniformity. Since the profile roll face remains parallel to the backup face, thickness readings can be taken from the center of the sheet. A drive mechanism (not shown) automatically adjusts the setting of the calender mill rolls. Continuous thickness of the material is indicated on a recorder unit C. This unit also houses the calender control monitor. The direct reading recording unit makes it possible to detect any change in or malfunctioning of the manufacturing process almost instantaneously. The permanent record also makes a valuable process research tool.

The radioisotope gage has the ability to check on its own accuracy. Once every 30 minutes the gage moves off the job and spends 45 seconds in recompensating itself for changes in humidity, temperature, accumulation of dirt, or any other environmental factor which might conceivably affect accuracy. Should the gage be unable to zero itself, it will shut off, ring a bell, and turn on a series of lights to show the operator where to look for the trouble.

Manufacturing Engineers Develop New Method to Statically Balance Speedometer Drag Cups



Small rotors having the shape of a thin disk often are statically balanced to equalize forces due to the action of gravity. Such is the case with a speedometer drag cup used to move the pointer which indicates car speed. Unbalance in the drag cup causes an error in speedometer calibration in addition to oscillation of the pointer as a result of car movement. A recent need for increasing the rate at which drag cups are balanced at AC Spark Plug Division required manufacturing engineers to develop a new balancing fixture. Using experience gained from two previously used types of balancing fixtures, plus the application of trigonometry fundamentals, AC engineers developed a fixture completely automatic in operation. The fixture automatically positions and punches three holes at the proper location to remove out-of-balance weight without the need for previous computations or measurements.

INCLUDED in the speedometer assembly of an automotive vehicle is a small rotating component called the drag cup, which performs the job of moving a pointer to indicate the speed of the vehicle. This shallow, aluminum cup is attached axially to the spindle of the pointer (Fig. 1). A permanent magnet, driven by a cable-casing assembly geared to the transmission, rotates inside the cup and exerts a magnetic drag, which causes the cup to rotate and move the pointer. The drag cup acts as an eddy-current torque unit and applies a torque to the pointer which is in direct proportion to the speed of rotation of the permanent magnet.

To obtain a straight-line calibration of vehicle speed versus pointer deflection and to reduce pointer oscillation due to car bounce, it is essential that the drag cup be statically balanced prior to placement in the speedometer assembly.

New Balancing Fixture Evolutionary in Nature

Each drag cup after being stamped has a certain amount of out-of-balance weight, which varies from cup to cup. To balance each cup, weight must be either added or removed.

The original method used by AC Spark Plug Division for balancing drag cups was to use a fixture which punched one hole and then machined another hole of larger diameter at the bottom of the cup. The hole was machined to just the correct depth to balance the cup. The depth of the machined hole was determined by

the angular rotation of the cup after the first hole was punched.

Because of mechanical difficulties the original balancing fixture was replaced by one which punched three holes, of the same diameter and at the same radius, in the outer rim of the drag cup¹ (Fig. 2). The quality of static balance possible was controlled by the skill and judgment of the operator. This fixture served satisfactorily until a recent need developed for increasing the rate at which drag cups were balanced. Using the experience gained from the two previous fix-

tures AC engineers set out to develop a fixture which would perform the static balancing operations automatically and at the same time remove the possibility of human error in the balancing operation. The result has been a static balancing fixture now being used which corrects the original unbalance of the drag cup automatically without the need for measurements or computations (Fig. 3).

Holes Positioned and Punched Automatically

Using the new balancing fixture, static balancing of a drag cup consists of three basic steps. A drag cup to be balanced is first supported on vibrating bearing supports so that it is free to rotate and come to rest with the heavy point of unbalance at the bottom (Fig. 4). The original unbalance of the cup is then changed by

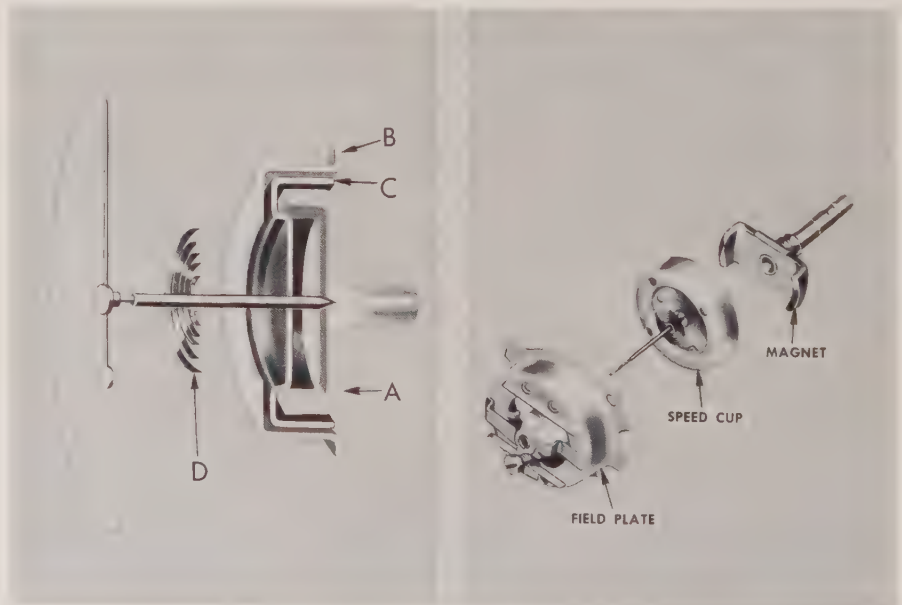
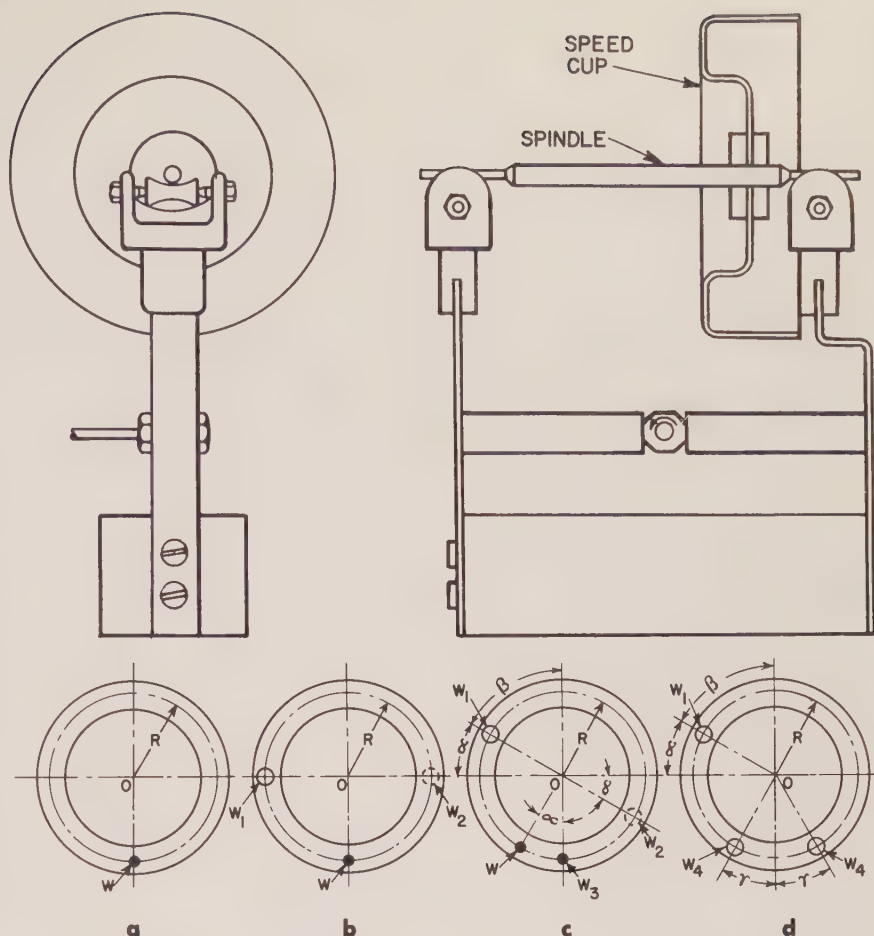


Fig. 1—The pointer of a speedometer is moved through the action of a rotating permanent magnet *A* a stationary field plate *B*, a non-magnetic movable drag, or speed, cup and spindle *C*, and a hair spring attached to the speed-cup spindle *D*. It is necessary to balance the speed cup to obtain a straight-line calibration of vehicle speed versus pointer deflection and to reduce pointer oscillation due to car bounce.

By NORMAN D. LAWLESS
AC Spark Plug
Division

Trigonometry fundamentals
aid in development of
automatic balancing fixture

Fig. 2—A previously used method for statically balancing speedometer drag, or speed, cups required the correction holes to be punched manually. The heavy side of the cup was determined first prior to the hole punching operation by placing the cup with attached spindle on oscillating roller bearings (top). The bearings operated parallel to the spindle length and caused the heavy side of the cup to rotate downward and rest at the bottom. With the heavy side of the cup W resting at the bottom (a) the first hole was then punched on the horizontal centerline of the cup and at right angles to the heavy side of the cup. The punched hole removed a weight W_1 from the cup, which was equivalent to adding an equal amount of weight W_2 on the opposite side (b). After the first hole was punched the cup rotated through an angle α and a new heavy side W_3 rested at the bottom (c). A special indicating pointer, when moved through the angle β and lined up with the first punched hole, automatically positioned the remaining two punches at the variable angle α on each side of the vertical centerline (d). The two holes were then punched simultaneously each removing a weight W_4 from the cup. This completed the balancing operation.



making in sequence two corrections, in the form of punched holes, of constant magnitude and angular relationship to the bottom of the drag cup. These two corrections either increase the unbalance or reduce it to a known range. The mean value of this range of unbalance is called the *equalized unbalance*. The third step consists of correcting the remaining unbalance by making a correction at the bottom of the cup equal in magnitude to the equalized unbalance.

Operation of Fixture Based on Trigonometry Fundamentals

The original unbalance of the drag cup is either increased or decreased to a

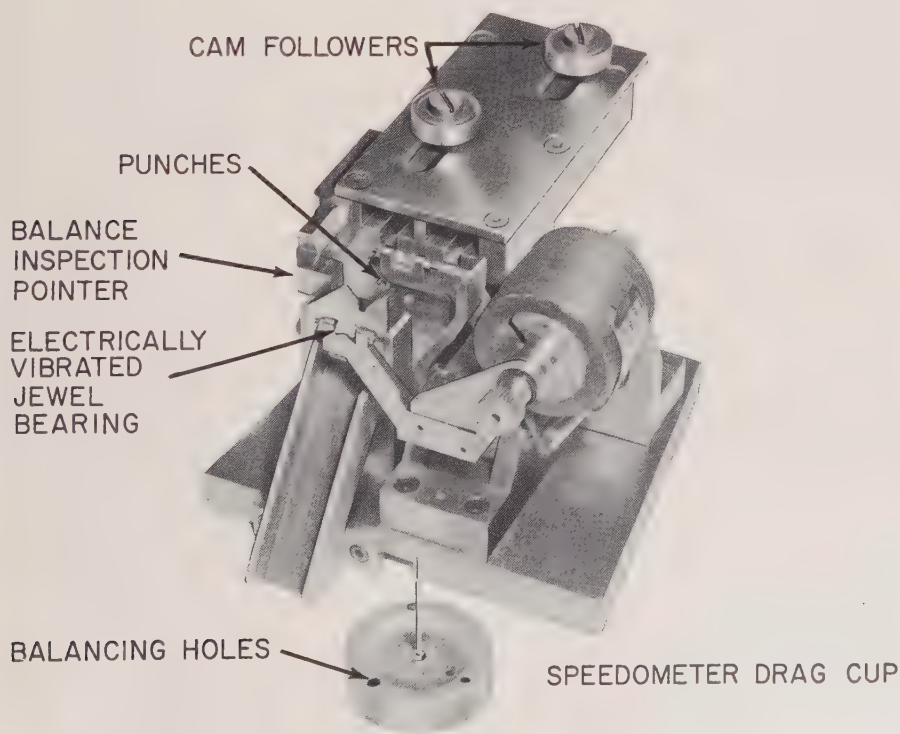


Fig. 3—The new fixture designed by AC engineers for the static balancing of speedometer drag cups has four basic components: (a) an electrically operated vibrator with sapphire jewel bearings for supporting the drag cup, (b) a 0.136-in. diameter punch and die operated by a slide and cam follower to punch a hole in the cup at a position of 30° from the bottom, (c) a 0.102-in. diameter punch and die operated by a second slide and cam follower to punch a hole at the bottom of the cup, and (d) a pointer to indicate whether the cup is balanced completely. For production operations, 18 of these fixtures are mounted on a continuously rotating table (Fig. 6).

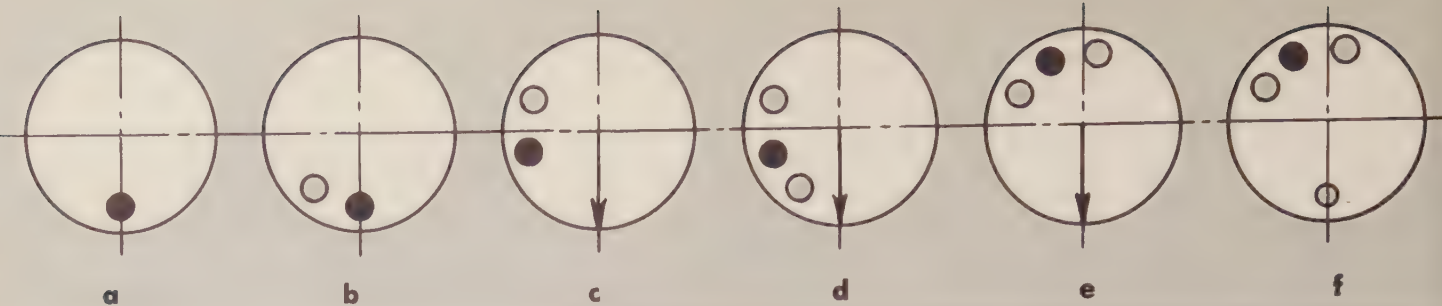


Fig. 4—The static balancing of a speedometer drag cup is carried out in six steps. The cup to be balanced is first placed on the vibrating bearing support. A 10-second period is allowed for the cup to come to rest, with the heavy point of unbalance at the bottom (a). A 0.136-in. diameter hole is then punched in the flange of the drag cup at a radius of 0.625 in. from the center and at a position of 30° from the bottom (b). Another 10-second period is allowed for the drag cup to rotate and come to rest in a new position, with a new heavy

point of unbalance at the bottom (c). A second 0.136-in. diameter hole is then punched in the cup at a position of 30° from the bottom (d). The cup is then allowed another 10-second period in which to rotate and bring a new heavy point of unbalance to the bottom (e). A 0.102-in. diameter hole is then punched at a radius of 0.625 in. at the bottom of the cup (f). This completes the balancing operation.

known range of unbalance when the first two holes are punched. The principle by which this is accomplished can be shown by a vector diagram (Fig. 5).

The amount of unbalance remaining after the first hole is punched can be represented by a vector, W_1 . The magnitude of this vector can be determined from the Law of Cosines as follows:

$$W_1 = \sqrt{W_x^2 + W_c^2 - 2W_xW_c \cos 30^\circ}$$

where

W_1 = resultant unbalance after first hole is punched

W_x = original unbalance

W_c = unbalance correction of hole punches at 30° from the bottom (0.00043 oz-in.).

The amount of unbalance remaining after the second hole is punched can be represented by a vector, W_2 (Fig. 5). The magnitude of this vector also may be determined from the Law of Cosines as follows:

$$W_2 = \sqrt{W_1^2 + W_c^2 - 2W_1W_c \cos 30^\circ}$$

where

W_2 = resultant unbalance after second hole is punched.

The vector diagram (Fig. 5) indicates that the terminus of vector W_2 will always lie along line A. The minimum value of W_2 , therefore, is equal to $(W_c) (\sin 30^\circ)$, or $0.5W_c$.

The maximum value of W_2 occurs at the positions indicated by lines B and C. Vector W_2 reaches a maximum value at line B when W_1 has a minimum value of $0.5W_c$. The maximum value of vector W_2 , therefore, when vector W_1 equals $0.5W_c$, is:

$$\begin{aligned} W_2 (\max) &= \sqrt{(0.5W_c)^2 + W_c^2 - W_c^2 \cos 30^\circ} \\ W_2 (\max) &= 0.62W_c. \end{aligned}$$

The maximum value of vector W_2 when at the position indicated by line C also is equal to $0.62W_c$. This, in turn, limits the maximum value of W_x to $2W_c$. The vector W_c , which represents the amount of correction obtained from punching a 0.136-in. diameter hole at a radius of 0.625 in., has a value of 0.00043 oz-in. The maximum unbalance, therefore, which can be corrected for with this method of static balancing will be equal to $2(0.00043)$, or 0.00086 oz-in.

The amount of unbalance after the second hole is punched varies between lines B and C. This amount of unbalance has a maximum value of $0.62W_c$ and a

minimum value of $0.5W_c$. The mean value of this range of unbalance is the equalized unbalance and is equal to:

$$\begin{aligned} \text{Equalized unbalance} &= \left(\frac{0.62W_c - 0.5W_c}{2} \right) + 0.5W_c = 0.56W_c. \end{aligned}$$

In the last two operations of the

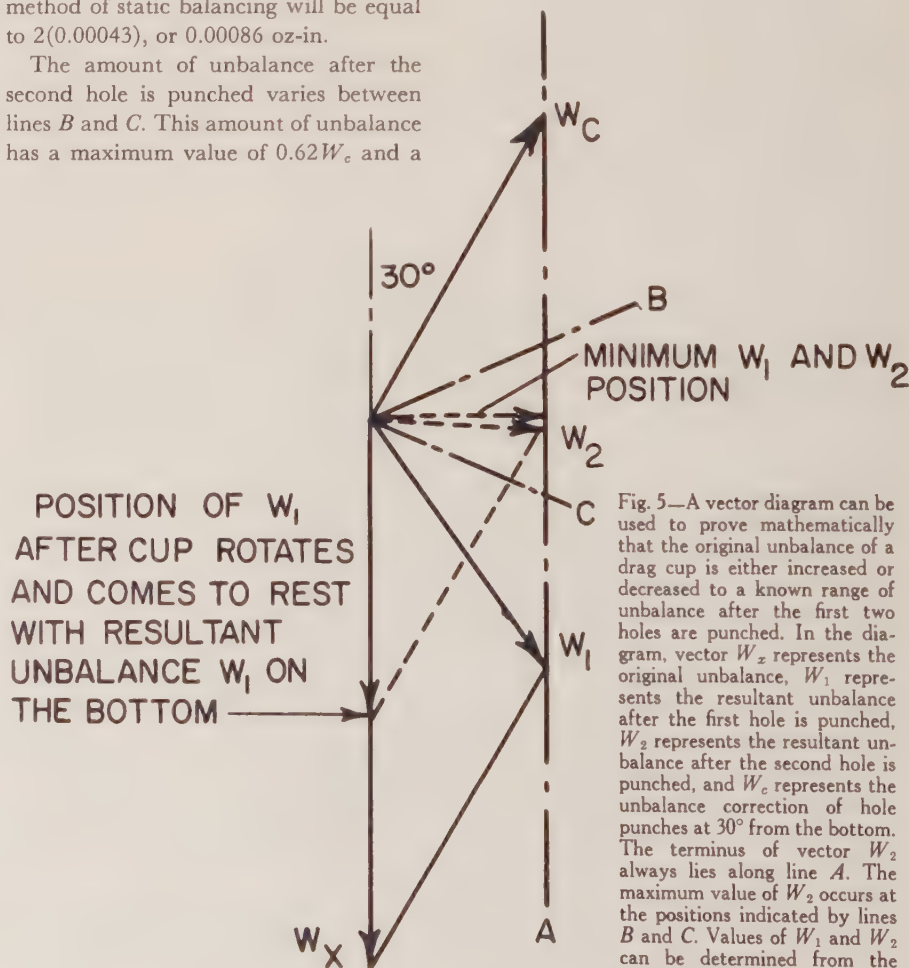


Fig. 5—A vector diagram can be used to prove mathematically that the original unbalance of a drag cup is either increased or decreased to a known range of unbalance after the first two holes are punched. In the diagram, vector W_x represents the original unbalance, W_1 represents the resultant unbalance after the first hole is punched, W_2 represents the resultant unbalance after the second hole is punched, and W_c represents the unbalance correction of hole punches at 30° from the bottom. The terminus of vector W_2 always lies along line A. The maximum value of W_2 occurs at the positions indicated by lines B and C. Values of W_1 and W_2 can be determined from the Law of Cosines.

balancing procedure the remaining unbalance is corrected for by punching a third hole at the bottom of the cup. The amount of this correction is equal to the equalized unbalance of $0.56W_c$.

Perfect balance for all drag cups cannot be obtained with the fixture. The last hole punched corrects for only the

mean value of W_2 . An unbalance may be left, therefore, in the drag cup equal in magnitude to the difference between the maximum or minimum values and the mean value of W_2 . The maximum unbalance error possible is equal to $0.62W_c - 0.56W_c$, or $0.06W_c$. This, in turn, equals 0.00026 oz-in.

The limit of unbalance of a drag cup for satisfactory operation in a speedometer is 0.0001 oz-in. The maximum possible error which might result from the balancing operation, therefore, is well within the production tolerance.

After the design of the fixture was perfected the next step was to devise a method for production balancing of the drag cups. The method used has 18 balancing fixtures mounted on a continuously rotating table (Fig. 6). The drag cups are loaded and unloaded manually by an operator. The correction holes are punched automatically as the fixtures rotate on the table.

Summary

The fixture developed for balancing speedometer drag cups differs basically from the conventional system of static balancing. In other systems of automatic balancing the angle and magnitude of the original unbalance is measured first by either a rotational or weighing process. The required amount of correction is then computed and applied automatically to the part being balanced. With the new fixture, the original unbalance of the drag cup is corrected without the need for measurements or computations. The three correction holes are placed automatically in the proper location by the self-positioning action of the drag cup as it is allowed to come to rest before each hole is punched.

By using a number of balancing fixtures on a continuously rotating table, a completely automatic balancing machine is obtained. The fact that no electronic or mechanical measuring devices are used plus the simplicity of mechanical design allows the balancing machine to be consistent and dependable.

Although the static balancing fixture was developed specifically for balancing speedometer drag cups it also could be used for static balancing many other small parts, such as flywheels and gyros.

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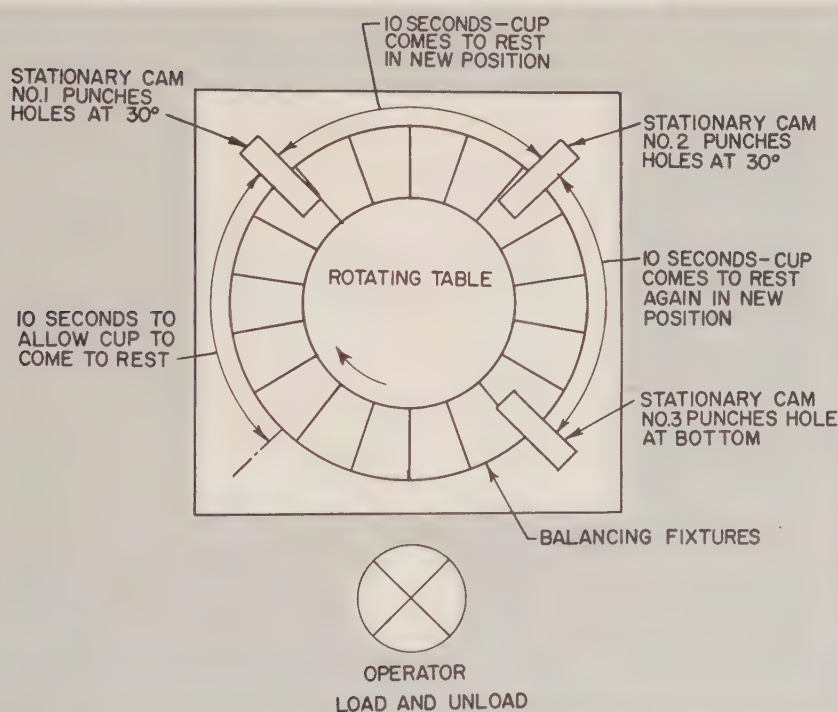
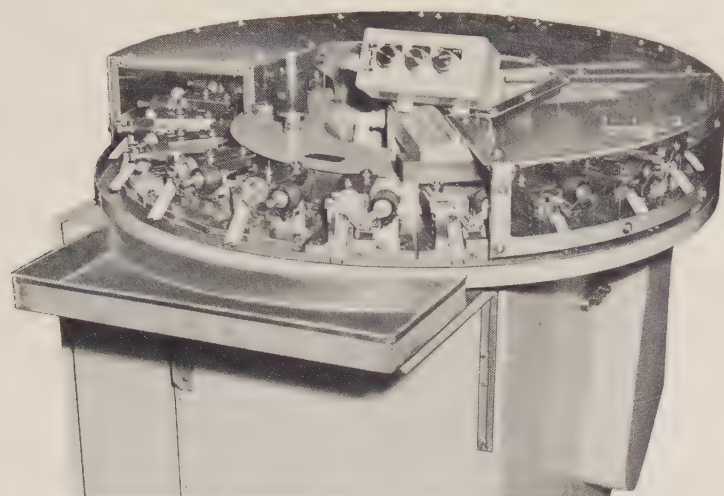


Fig. 6—Production balancing of speedometer drag cups is carried out by 18 balancing fixtures mounted on a continuously rotating table (top). The drag cups are loaded and unloaded manually by an operator at the front of the machine. The correction holes are punched automatically into the drag cup as the balancing fixtures travel around the table and pass under three stationary cams (bottom). To provide sufficient time for the cups to come to rest before each hole is punched, the stationary cams are spaced 90° apart. The first and second cams operate the 30° punch and the third cam operates the bottom punch. A pointer is provided on each balancing fixture to indicate whether or not the cups are balanced completely. The pointer indicates if the first hole punched in the cup rotates more than 70°. It was found that a drag cup with an unbalance greater than the maximum unbalance possible to correct with the fixture would rotate less than 70°. The cups which indicate that they have not been balanced completely are left on the table and are further balanced as they travel around a second time. Only a few of the drag cups to be balanced require more than one cycle around the table.

A Dilemma of Group Research— Determination of “Inventorship”

By RICHARD P. BARNARD

Patent Section

Central Office Staff

THE patent laws are explicit in requiring that an application be filed in the name of the inventor, or inventors, whose contribution to the arts or sciences is represented by the invention.

Pursuant to these laws, the courts will normally find a patent to be invalid where there has been a misjoinder of inventors—that is, designating the wrong inventor or the wrong combination of inventors. The law and the courts are consistent in requiring a patent to be granted only to that person who has “exercised an inventive faculty” (exercised more than routine skill) or to those persons who have together exercised such faculties to create the subject of the patent grant. Thus, the potential penalty for an error in the matter of *inventorship* is complete and total loss of the property right represented by the patent. Where the fact of misjoinder of inventors can be proven, the patent is invalid notwithstanding the absence of fraud or the intent of the parties to act in good faith.

The facts relating to inventorship may be obscured, overlooked, or ignored where, as in a corporation, a number of persons work together to achieve a desired result. Frequently, the attainment of the result is of much more immediate importance to the parties than which of them contributed the inventive concept involved. Whatever the motivation, however, an error in the matter of inventorship potentially foredooms the patent grant.

Accordingly, it will be well to touch on some of the more salient considerations regarding sole or joint inventorship.

Unfortunately, there are no exact rules by which the matter of inventorship can be determined where a cooperative effort has produced an invention. While exact rules are absent, there are both negative and positive guide posts which can be used to indicate conditions under which sole or joint inventions have taken place.

First, consider the case where there has been a group assignment to solve a particular problem or to achieve a given result. If the conception for achieving

the desired result, and the means whereby such result is achieved, represents the contributions of one person then it is clear that a sole invention has taken place.

The developmental stage at which the “inventive faculty” may be exercised is unpredictable, and whether early or late has no effect on the fact of inventorship. The mere isolation of a problem may constitute the invention. This may be illustrated by a situation in which considerable trouble was experienced in the operation of a compressor under certain operating conditions. The inventor, in this case, analyzed the problem and traced it to a failure to vent properly a particular portion of the compressor system. Thereafter, a co-worker performed the routine of designing the vent. It is clear that a sole invention was made in the discovery of the cause of the problem.

On the other hand, the efforts of many people working in concert may be brought to fruition by the insertion of the inventive key by one of their number after the others have provided all but the missing element. Under these circumstances, a sole invention may again result.

Joint Contributions Need Not Be Equal

The greatest difficulty arises in the case where there appears to have been a joint invention. In this case it is necessary to appraise the contributions of several parties to ascertain whether one or several supplied that quantum necessary to constitute invention. First, it is not necessary that the contributions of joint inventors be equal either quantitatively or qualitatively. In fact, it is possible that one inventor may have made a relatively minor contribution and still be considered a joint inventor. Here again, it is necessary to advert to the standard of the “exercise of inventive faculties.” While recognizing that invention is something more than the exercise of ordinary skill in a particular art, one may exercise his inventive faculty to a greater degree than another in creating what may be properly considered a joint invention.

When is an invention

sole or joint?

Technical Inability Not Penalized

Joint inventors need not contribute in the same way to a common invention. One party might conceive the solution to a problem and another the means for implementing the solution. It is still, however, a joint invention. The fact that one party had no part in the actual construction of a machine has been held not to negate joint invention. An extension of this illustration is the case of a party having an idea but not being technically or scientifically equipped to express his idea in a workable form. This party, therefore, collaborates with a technician or a scientist who gives physical or practical expression to the nascent idea. Depending on the extent of the contribution of the technician or scientist, either a sole or joint invention may take place.

Certain recurring misconceptions suggest additional guide posts to be staked out along the path leading to a correct determination of inventorship.

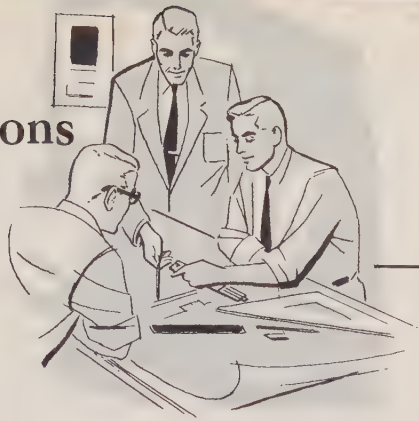
Status of Supervisor

A supervisory status does not, for that reason alone, entitle one to pre-empt entirely or even to share as co-inventor of a subordinate's invention. Further, assignment of a problem for solution does not constitute one an inventor unless the problem is presented in a way to make the solution obvious to one skilled in the art. On the other hand, it is no less an error for the creative supervisor, out of a misplaced sense of modesty or loyalty, to credit his invention, in whole or in part, to a subordinate. The preceding observations are particularly likely to plague the individual responsible for directing the research or developmental efforts of other individuals.

Conclusion

Commercial exploitation of a patented invention is normally undertaken with the assumed assurance that others may

Notes About Inventions and Inventors



Contributed by
Patent Section
Central Office Staff

be excluded from practicing the invention for a limited period. Capital investment frequently makes this assurance a necessity. To prematurely lose this constitutionally provided assurance, as may happen through an improper determination of inventorship, may result in economic loss.

THE following is a general listing of patents granted in the names of General Motors employees during the period May 1, 1957 to July 31, 1957.

AC Spark Plug Division Flint, Michigan

- **Ralph O. Helgeby**, *M.E. degree, Horton School of Technology, Norway, and General Motors Institute* staff engineer, inventor in patents 2,793,605 and 2,798,174 for a continuous vivid arc instrument and a no tipping error speed cup instrument, respectively.
- **Karl Schwartzwalder**, (*B. Cer. E., 1930, and M.S., 1931, The Ohio State University*) director of research, Ceramic Laboratory, and **Curtis D. Ortman**, senior engineer, Ceramic Laboratory, inventors in patent 2,793,956 for a sodium silicate type cement.
- **Robert W. Smith**, (*Ph. D., University of Michigan, 1933*) supervisor, Physics and Metallurgy Laboratories, inventor in patent 2,794,059 for a sealed tip thermocouple.
- **Bertil H. Clason**, (*Coethen Polyteknikum, Germany, and Tekniska Skolan, Sweden*) senior project engineer, Automotive Engineering Department, inventor in patent 2,794,879 for an electrical device.
- **Ralph H. Mitchel**, (*B.S.E.E., University of Michigan, 1929*) senior project engineer, Engineering Department, inventor in patent 2,800,383 for a process for making a gaseous discharge tube.
- **Roy L. Bowers**, (*B.S., Michigan State University, 1930*) staff engineer, Engineering Department, inventor in patent

2,801,009 for a filter having outwardly extending pleats.

- **Earl W. Pierce**, (*B.S.M.E., University of Michigan, 1939*) senior project engineer, Automotive Engineering Department, inventor in patent 2,801,384 for a spark plug testing apparatus.

Allison Division Indianapolis, Indiana

- **John B. Wheatley**, (*A.B.M.E., 1929, and M.E. in aeronautics, 1930, Stanford University*) assistant chief engineer, Advanced Design Engineering Department; **Otaker P. Pracher**, (*B.S.M.E., University of Minnesota, 1934, and M.E., University of Minnesota, 1936*) head, Research Group; **Arthur W. Gaubatz**, (*B.S., University of Wisconsin, 1920*) senior project engineer, Experimental Engineering Department; and **Donald G. Zimmerman**, (*B.S.M.E., Purdue University, 1940*) section chief on design projects, Power Turbine Engineering Department, inventors in patent 2,791,091 for power plant cooling and thrust balancing systems.
- **Howard W. Christenson**, (*B.S., Oregon State College, 1938*) chief engineer, inventor in patent 2,792,716 for an automatic transmission for vehicles.
- **Arthur W. Gaubatz***, inventor in patents 2,793,023 and 2,797,812 for a centrifugal governor and a self cleansing filter, respectively.
- **Arthur W. Gardiner**, (*A.B. degree, Swarthmore College, 1920*) special assignment, Advanced Design and Development Engineering Department, inventor in patent 2,793,491 for a variable area jet nozzle.
- **Harry C. Karcher**, (*B.S. Aero. E., Massachusetts Institute of Technology, 1925*), chief, Field Service Department, inventor in patent 2,793,495 for a jet

propulsion apparatus with expansibly mounted fuel manifold.

- **John B. Wheatley*** and **Donald G. Zimmerman***, inventors in patent 2,793,832 for a means for cooling stator vane assemblies.
- **Victor W. Peterson**, (*B.S.M.E., Rose Polytechnic Institute, 1939*) Advance Design and Development Engineering Department, inventor in patent 2,796,139 for a thrust nut lock.
- **Otaker P. Pracher*** and **Ronald M. Hazen**, (*B.S.M.E., University of Michigan, 1922*) technical assistant to the general manager, inventors in patent 2,798,360 for a ducted fan type jet propulsion engine.
- **Eugene C. Van Cleave**, (*A.B. in physics, Wabash College, 1940*) senior experimental engineer, Electronics and Parts Test Department, inventor in patent 2,798,383 for a rotor balancing bolt lock.
- **John L. Goldthwaite**, (*B.S.C.E., Purdue University, 1921*) special assignment, Engineering Department, and **Stuart Wilder, Jr.**, no longer with GM, inventors in patent 2,799,918 for compressor blade manufacture.
- **John B. Wheatley***, **Arthur W. Gaubatz***, and **Fred R. Short**, (*B.S.M.E., Georgia Institute of Technology, 1939*) group head, fluid dynamics research, Engineering Department, inventors in patent 2,800,273 for compressor inlet de-icing.
- **Wilgus S. Broffitt**, (*B.S.M.E., University of Kentucky, 1938*) head, Design Group, inventor in patent 2,801,075 for a turbine nozzle.

Aeroproducts Operations Allison Division Dayton, Ohio

- **Howard M. Geyer**, (*B.S.I.E., University of Alabama, 1940*) chief research engineer, Engineering Department, and **James N. Tootle**, (*B.S.E., University of Mich-*

igan, 1943) supervisor—actuator design, Engineering Department, inventors in patent 2,791,128 for a rotary actuator.

- **Kenneth L. Berninger**, (*Purdue University*) senior project engineer, Engineering Department; **William S. Neff, Jr.**, not with Aeroproducts; and **William A. Weis**, (*B.S.E., University of Dayton, 1938*) senior designer, Engineering Department, inventors in patent 2,791,237 for a valve assembly.

- **John H. Smith**, (*B.S.M.E., University of Michigan, 1949*) senior project engineer, Engineering Department, inventor in patent 2,792,064 for a variable pitch propeller.

- **Howard M. Geyer*** inventor in patent 2,793,503 for an actuator system.

- **John D. Moeller**, (*B.S.A.E., B.N.S., Purdue University, 1949*) senior project engineer—turbine group, Engineering Department; **Clifford B. Wright**, (*A.B., Wittenberg College, 1938*) chief engineer, Aircraft Products; and **Thomas Barish** and **Robert C. Treseder**, no longer with GM, inventors in patent 2,797,761 for a propeller mechanism.

- **Dale W. Miller**, (*B.S., Wittenberg College, 1934*) assistant chief engineer, Engineering Department, and **Virgil Battenberg**, (*University of Dayton*) senior project engineer, Engineering Department, inventors in patent 2,798,563 for a propeller control.

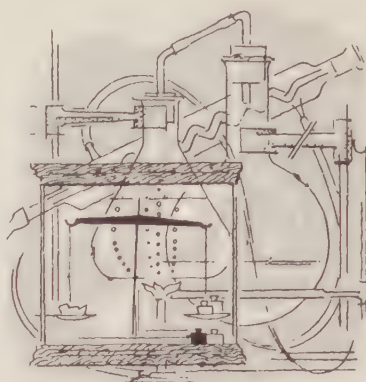
Buick Motor Division Flint, Michigan

- **Charles A. Chayne**, (*B.S.M.E., Massachusetts Institute of Technology, 1919 and Harvard University*) now vice president in charge of GM Engineering Staff, inventor in patent 2,791,263 for a seat adjuster.

- **Lloyd E. Muller**, (*B.S.M.E., University of Kansas, 1929*) staff engineer, Engineering Department, inventor in patent 2,799,902 for a silencing baffle for defroster outlet.

- **Lloyd E. Muller*** and **George R. Bayley**, (*General Motors Institute, 1929*) associate staff engineer, Engineering Department, inventors in patent 2,800,285 for heating, ventilating, and defrosting systems.

- **Lloyd E. Muller*** and **Beecher B. Cary**, no longer with GM, inventors in patent 2,800,973 for a retroverted flow muffler.



Cadillac Motor Car Division Detroit, Michigan

- **Philip W. Maurer**, (*General Motors Institute, 1934*) assistant staff engineer, Engineering Department, inventor in patent 2,791,100 for a vehicle refrigerating apparatus.

- **Hugo H. Wendela**, (*B.S. Aero. E., Wayne State University, 1936*) assistant staff engineer, Engineering Department, inventor in patent 2,791,957 for a ventilator valve assembly.

- **George L. Rothrock**, (*Syracuse University*) staff engineer, Engineering Department, and **William J. Tell**, retired, inventors in patent 2,792,261 for an ornamental wheel cover.

- **Harold J. McCotter**, (*B.S.E.E., University of Michigan, 1928*) senior project engineer, Engineering Department, inventor in patent 2,793,539 for a brake pedal structure.

- **Therell L. Sipe**, (*Lawrence Institute of Technology, 1949*) tool engineer, Methods and Equipment Department, Cleveland Ordnance Plant, inventor in patent 2,795,159 for a stud setting torque device and the like.

Chevrolet Motor Division Detroit, Michigan

- **Richard C. Stolte**, (*Purdue University*) motor engineer, Research and Development, inventor in patent 2,791,287 for a hydraulic power steering mechanism.

- **Adelbert E. Kolbe**, future engine design engineer, Engine Design Depart-

ment, inventor in patent 2,793,625 for an engine frame.

- **Richard F. Burdette**, assistant manager, Sales Department, and **Edwin S. Cobb**, (*Tufts University*) regional service and mechanical engineer, Sales Department, inventors in patent 2,795,523 for a method of repairing automobile sheet metal panels.

- **Theodore J. Soroka**, (*Lawrence Institute of Technology and General Motors Institute*) assistant staff engineer, Engineering Department, inventor in patent 2,797,947 for a latch mechanism.

- **Norman A. Holly**, (*Wayne State University and University of Michigan*) design engineer, Engineering Department, and **John T. Ford**, (*Certificate, Chrysler Institute of Technology, 1939*) senior project engineer, Engineering Department, inventors in patent 2,798,632 for an ash tray assembly.

- **William S. Wolfram**, (*B.S. Auto. E., University of Michigan, 1932*) assistant staff engineer, Research and Development Department, and **Walter T. Czuba**, no longer with GM, inventors in patent 2,800,037 for an automotive power plant.

- **Raymond E. Dunn**, (*University of Illinois*) assistant staff engineer, Engineering Department, inventor in patent 2,800,800 for an anti-rattle device.

Cleveland Diesel Engine Division Cleveland, Ohio

- **William E. Brill**, (*B.S., Case Institute of Technology, 1924*) assistant chief engineer, Engineering Department, inventor in patent 2,793,078 for fuel injection.

Delco Appliance Division Rochester, New York

- **Cyril T. Wallis**, (*Technical School, Cambridge, England*) patent and new devices contact, Engineering Department, inventor in patents 2,790,989, 2,790,990 and 2,797,428 for a windshield wiper shaft assembly, a windshield wiper arm assembly, and a flexible squeegee, respectively.

*Inventors' names marked with an asterisk have biographical listings noted previously in this issue's Notes About Inventions and Inventors.

● **Cyril T. Wallis*** and **Frederick E. VonSchlichten**, (*B.S.E.E., University of Wisconsin, 1931*) process engineer, Process Engineering Department, inventors in patent 2,791,244 for a method and apparatus for dispensing measured quantities of liquid to jewel bearings.

● **Peter R. Contant**, senior project engineer, Engineering Department, inventor in patent 2,800,799 for an electric clock drive.

*Delco Radio Division
Kokomo, Indiana*

● **Bertram A. Schwarz**, technical assistant to the general manager, inventor in patent 2,800,027 for a mechanical radio tuning means.

● **William R. Kearney**, (*B.S.M.E., Purdue University, 1933*) senior project engineer, Mechanical Engineering Section, and **Manfred G. Wright**, (*B.S.M.E., Purdue University, 1938*) head, Mechanical Engineering Section, inventors in patent 2,800,587 for a manual powered tuner.

*Delco-Remy Division
Anderson, Indiana*

● **William E. Brown**, (*General Motors Institute*) staff engineer, Product Engineering Department, inventor in patent 2,791,677 for a glove compartment lamp mounting and switch.

● **Willard C. Shaw**, (*Ball State University*) general foreman, Engineering Model Shop, and **Harold V. Elliott**, (*General Motors Institute*) senior project engineer, Engineering Department, inventors in patent 2,794,884 for a circuit breaker.

● **William E. Brown*** and **Ward Cole**, product engineer, Engineering Department, inventors in patent 2,800,541 for a direction signal switch.

*Detroit Diesel Engine Division
Detroit, Michigan*

● **John Dickson**, (*Royal Technical College, Glasgow, Scotland*) staff engineer-in-charge of forward design, Engineering Department, inventor in patent 2,791,989 for an internal combustion engine.

*Diesel Equipment Division
Grand Rapids, Michigan*

● **Herbert H. Black**, (*General Motors Institute, 1933*) assistant chief engineer, Product Engineering Department, inventor in patent 2,797,673 for a valve lifter.

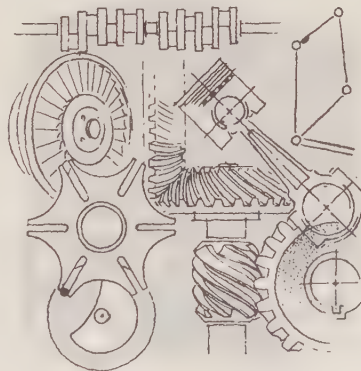
*Electro-Motive Division
LaGrange, Illinois*

● **James E. Hencken**, motor and generator mechanical design engineer, Engineering Department, and **William J. Derner**, no longer with GM, inventors in patent 2,801,394 for an electrical terminal box.

*GM Engineering Staff
Detroit, Michigan*

● **Lothrop M. Forbush**, (*B.S., Harvard University, 1939* and *Massachusetts Institute of Technology*) assistant engineer-in-charge, Automotive Ordnance Section, inventor in patent 2,791,297 for a multiple shoe type expanding brake.

● **John T. Marvin**, (*B.S. Chem. E., Case Institute of Technology, 1934* and *Western Reserve University and Franklin College*) patent attorney, Patent Section, Dayton Office, inventor in patent 2,793,427 for friction material.



● **Charles N. McCarthy**, (*International School of Correspondence, 1928*) chassis engineer, Passenger Car Development, inventor in patent 2,795,969 for a final drive means.

● **George P. Ransom**, (*B.S.M.E., University of Michigan, 1949*) section engineer,

Power Development Section, and **Earl R. Pierce**, no longer with GM, inventors in patent 2,797,675 for a thermostatic control means.

● **Charles A. Chayne***, (*B.S.M.E., Massachusetts Institute of Technology, 1919*, and *Harvard University*) vice president in charge of Engineering Staff and **John Dolza**, retired, inventors in patent 2,798,663 for a refrigerating apparatus.

● **Willard F. Wagner**, (*L.L.B., Wayne State University, 1953* and *Michigan State University*) patent attorney, Patent Section, Central Office, inventor in patent 2,800,540 for a directional signal.

*Fisher Body Division
Detroit, Michigan*

● **Eric J. Opitz**, (*M.E. degree, Leipzig, Germany, 1926*) senior engineer-in-charge, Tool Department, inventor in patent 2,791,094 for a pressure backup system for a press.

● **Walter Schumaker**, engineer-in-charge, Front Seats and Under Bodies Department, and **Robert A. Stone**, no longer with GM, inventors in patent 2,791,465 for a hinged finish molding.

● **James H. Wernig**, (*Johnson School of Body Design and Engineering, and Alexander Hamilton Institute*) general director of engineering and related activities, inventor in patent 2,793,070 for a weatherstrip seal for automobile rear compartment.

● **Engelbert A. Meyer**, senior project engineer, Engineering Department, inventor in patent 2,793,071 for a window clip assembly for automotive vehicles.

● **Clarence P. McClelland**, (*University of Detroit*) senior project engineer, Design and Drafting Engineering Department, inventor in patent 2,795,145 for a windshield wiper drive cable apparatus.

● **Clyde H. Schamel**, (*B.S.E.E., University of Notre Dame, 1927*) assistant senior engineer-in-charge, Experimental and Development Department, inventor in patent 2,795,452 for a lock striker assembly.

● **Francis E. Smith**, (*B.S., University of Detroit, 1930*) senior staff assistant, Design and Drafting Engineering Department, and **Ben J. Smith**, no longer with GM,

inventors in patent 2,795,456 for a convertible top and hinged finish molding therefor.

- **James D. Leslie**, (*B.M.E., University of Detroit, 1939*) engineer-in-charge, Mechanical Department, inventor in patent 2,796,276 for a rotary bolt door latch.

- **Joseph E. Kubacka**, (*Columbia University, Detroit Institute of Technology, and Wayne State University*) senior engineer-in-charge, Experimental and Development Department, inventor in patent 2,800,361 for a dual closure interlock for vehicle luggage and foldable-top stowage compartments.

- **Clarence P. McClelland***, **James H. Wernig***, and **Armas G. Makela**, no longer with GM, inventors in patent 2,800,676 for a windshield wiper arm and blade assembly.

- **Napoleon P. Boretti**, (*B.E.E., University of Detroit, 1935*) assistant engineer-in-charge, Process Development Department, inventor in patent 2,800,916 for a sediment discharge valve.

Frigidaire Division Dayton, Ohio

- **Charles C. Whistler, Jr.**, (*B.S.M.E., Purdue University, 1944*) senior project engineer, Research and Future Products Engineering, inventor in patent 2,792,-201 for a heat exchanger.

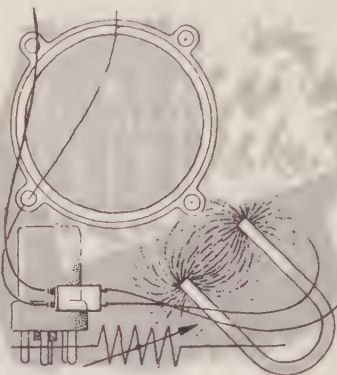
- **Millard E. Fry**, (*B.S.M.E., University of Pittsburgh, 1931*) senior project engineer, Appliance Engineering Department, inventor in patents 2,792,486 and 2,798,-144 for a domestic appliance in each case.

- **John M. Murphy**, (*B.S.E.E., Purdue University, 1930*) section engineer, Engineering Department, and **Leonard J. Mann**, (*M.E., University of Cincinnati, 1940*) senior project engineer, Engineering Department, inventors in patent 2,792,691 for a two compartment refrigerator.

- **Ira L. Gould**, (*B.S.M.E., New Mexico Agricultural and Mechanical Arts College, 1948*) senior project engineer, Air Conditioning Engineering, and **Charles F. Henney**, retired, inventors in patent 2,793,834 for a vehicle refrigerating apparatus.

- **Edmund F. Schweller**, assistant chief engineer, inventor in patent 2,794,243 for a method of brazing corrugated fins to flat tubing.

- **Harold C. Pearson**, (*B.S.M.E., University of Cincinnati, 1936*) senior project engineer, Refrigerated Appliances Engineering, and **Francis I. Rataiczak**, not with GM, inventors in patent 2,794,323 for a refrigerating apparatus with overload control.



- **Wendall B. Shearer**, (*General Motors Institute, 1946*) project engineer, Refrigerated Appliances Engineering, inventor in patent 2,794,325 for a refrigerated display case.

- **Jesse L. Evans**, (*B.S.M.E., University of Dayton, 1943*) senior project engineer, Engineering Department, inventor in patent 2,794,434 for an illuminated oven with viewing means.

- **Everett C. Hutchins**, (*Eastern State College*) foreman—welding machine repair, Maintenance Department, inventor in patent 2,795,039 for a method of frictionally welding a tube to a metal object.

- **Clifford H. Wurtz**, (*B.S., University of Illinois, 1929*) supervisor of major product line, inventor in patent 2,795,113 for a refrigerating apparatus.

- **Kenneth O. Sisson**, (*B.S.M.E., South Dakota State College, 1936*) senior project engineer, Appliance Engineering Department, inventor in patent 2,795,126 for a clothes washing machine.

- **Leonard J. Mann***, inventor in patent 2,797,720 for a sheet metal nut with screw slot having frangible serrations.

- **Robert D. Bremer**, (*B.S.E.E., Purdue University, 1934*) senior project engineer, Non-Refrigerated Appliances Engineering, inventor in patent 2,799,767 for an electric heater arrangement.

- **Harry F. Clark**, (*E.E., University of Cincinnati, 1921*) senior project engineer, Engineering Department, inventor in patent 2,801,312 for an electrical apparatus.

- **George C. Pearce**, (*B.S.M.E., Stanford University, 1924*) section head, Appliance Engineering Department, inventor in patent 2,801,325 for a domestic appliance.

Guide Lamp Division Anderson, Indiana

- **Lloyd T. Fuqua**, (*DePauw University and the American School of Chicago*) senior designer—drafting, Engineering Department and **Harry C. Doane**, assistant to the vice president in charge of GM Engineering Staff, inventors in patent 2,791,721 for headlight control.

- **Edward L. Barcus**, senior designer—drafting, Engineering Department, inventor in patent 2,798,913 for a direction signal control.

- **Edward L. Barcus***, **Lloyd T. Fuqua*** and **Robert N. Falge**, retired, inventors in patent 2,800,542 for a direction signal.

- **Robert N. Falge*** and **Howard C. Meade**, (*Western Reserve University*) chief engineer, inventors in patent 2,800,641 for a vehicle tail, stop, and turn signal lamp.

Harrison Radiator Division Lockport, New York

- **John R. Holmes**, retired, **John W. Godfrey**, (*B.S. Chem., Canisius College, 1935*) assistant chief engineer, Product Engineering Department, and **Robert F. Caughill**, (*M.E., Clarkson College, 1947*) supervising engineer, industrial section, Engineering Department, inventors in patent 2,796,239 for a heat exchanger.

- **John R. Holmes*** and **Charles F. Arnold**, (*B.S.M.E., University of Cincinnati, 1923*) chief engineer, Cadillac Motor Car Division, inventors in patent 2,800,086 for a heating, ventilating, and windshield defrosting apparatus.

*Inland Manufacturing Division
Dayton, Ohio*

• **John F. O'Brien**, (*B.S., Notre Dame, 1940*) sales representative, Sales Department; **Arthur J. Frei**, senior project engineer, Engineering Department; and **Harry O. Waag**, head, Paint Laboratory, Engineering Laboratory, inventors in patent 2,800,775 for a freezing device.

• **Max P. Baker**, (*A.B., Miami University, 1922*) project engineer, Engineering Department, and **Frederick W. Sampson**, (*M.E., Cornell University, 1924*) now section engineer on special assignment, Moraine Products Division, inventors in patent 2,800,777 for a torque transmitting device.

*Moraine Products Division
Dayton, Ohio*

• **Richard C. Rike**, (*General Motors Institute*) section engineer, Engineering Department, inventor in patent 2,793,501 for a direct acting master cylinder.

• **Frederick W. Sampson***, (*M.E., Cornell University, 1924*) section engineer on special assignment, inventor in patent 2,793,793 for a metering device.

*New Departure Division
Bristol, Connecticut*

• **Leland D. Cobb**, (*E.E., Pratt Institute, 1928*) manager, Research and Development Laboratory, inventor in patent 2,793,729 for a one way clutch.

• **Clyde Hayden**, (*B.S.M.E., Northeastern University, 1936*) project engineer, Product Engineering Department, inventor in patent 2,795,308 for a sprag clutch.

*Packard Electric Division
Warren, Ohio*

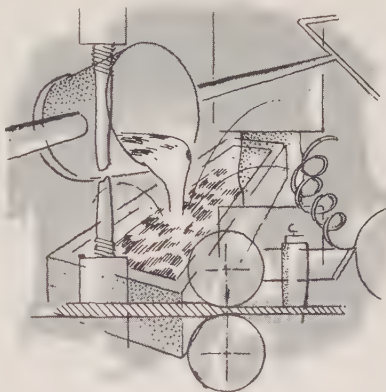
• **Robert C. Woofter**, (*Fenn College*) chief, Assembly Components Design Section, inventor in patent 2,792,558 for a spark plug boot and terminal.

*Pontiac Motor Division
Pontiac, Michigan*

• **Clayton B. Leach**, (*A.B. in mathematics and chemistry, Park College, 1934 and General Motors Institute*) chassis engineer, Engineering Department, inventor in patent 2,792,820 for a camshaft and fuel pump drive gear.

*GM Process Development Staff
Detroit, Michigan*

• **Robert A. Spaulding**, (*B.S.Chem.E., University of Illinois, 1945, M.S., Purdue University, 1949*) senior plating engineer, Engineering Department, and **Clarence G. Chambers**, (*General Motors Institute, 1932; B.S.M.E., Wayne State University, 1937*) supervisor, Laboratories, inventors in patent 2,791,516 for electroless plating.



*GM Research Staff
Detroit, Michigan*

• **Warren H. Smith**, (*B.S.M.E., Purdue University, 1928*) supervisor of design, Mechanical Development Department, inventor in patent 2,792,817 for an internal combustion engine.

• **Claude J. Kinsey**, general supervisor, Drafting and Design, Special Problems Department, inventor in patent 2,795,978 for a shield device.

• **Archie D. McDuffie**, (*General Motors Institute*) now assistant department head, Power Development Section, GM Engineering Staff, inventor in patent 2,796,243 for a carburetor.

• **Dean K. Hanink**, (*B.S.Met.E., University of Michigan, 1942*) now chief metallurgist, Metallurgical Department, Allison Division, inventor in patent 2,798,827 for a method of casting and heat treatment nickel base alloys.

• **Albert F. Welch**, (*B.S.E.E., Tufts College, 1948*) assistant head, Instrument Section, and **Wesley S. Erwin**, deceased, inventors in patent 2,800,014 for an engine power indicator.

*Rochester Products Division
Rochester, New York*

• **Howard H. Dietrich**, (*B.S.E.E., Purdue University, 1926 and Yale University*) patents, new devices and project analysis engineer, Engineering Department, inventor in patent 2,791,995 for an anti-detonation device for a carburetor.

• **Elmer Olson**, (*Lewis Institute*) and **Robert H. Sternaman**, (*B.S.M.E., Purdue University, 1929*) senior contact engineer, Product Engineering Department, inventors in patent 2,792,203 for a carburetor.

• **Elmer Olson*** inventor in patents 2,793,844, 2,797,905 and 2,800,314 for a carburetor, in each case.

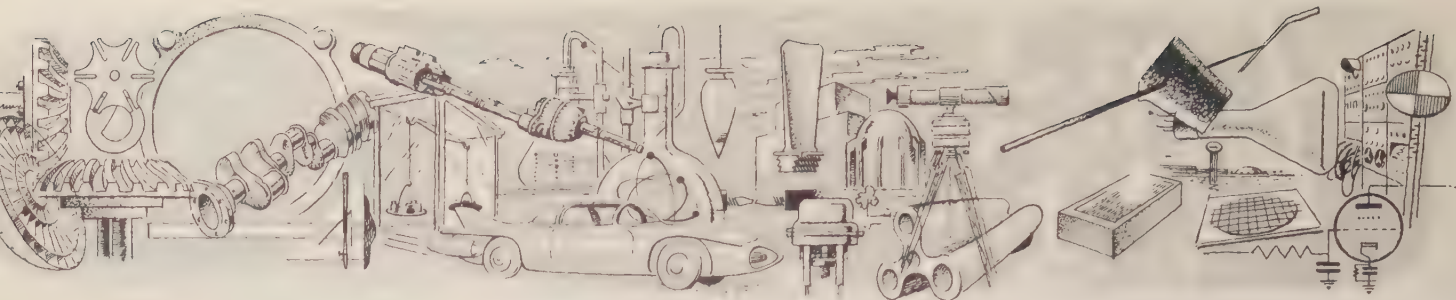
• **Arthur W. Winter**, (*University of Detroit*) staff engineer—laboratory and road testing, Product Engineering Department, inventor in patent 2,798,704 for a carburetor.

• **Frederick W. Cummings**, (*B.S.M.E., Clarkson College*) administrative engineer, Engineering Department, and **Henry D. Mowers**, production engineer, Production Engineering Department, inventors in patent 2,798,933 for an apparatus for making electric wiring conduits.

*Saginaw Steering Gear Division
Saginaw, Michigan*

• **Arthur F. Bohnhoff**, (*B.S.M.E., Michigan College of Mining and Technology, 1938*) senior designer, Engineering Department, and **Dimitar Toschkoff**, (*B.S.M.A., Technical College, Sophia, Bulgaria, 1937*) now senior project engineer, Automotive Engineering Department, AC Spark Plug Division, inventors in patent 2,791,185 for a hydraulic rotary transmission device.

*Inventors' names marked with an asterisk have biographical listings noted previously in this issue's Notes About Inventions and Inventors.



• **C. W. Lincoln**, (*B.S., University of Illinois, 1916*) technical assistant to general manager; **John A. Olson**, no longer with GM; **Joseph J. Verbrugge**, (*General Motors Institute, 1941*) senior project engineer, Product Engineering Department; and **Philip B. Zeigler**, (*B.S.E., Purdue University, 1941*) chief engineer, Product Engineering Department, inventors in patent 2,792,463 for a safety switch.

• **Arthur F. Bohnhoff*** and **Paul V. Wysong**, (*University of Kansas*) sales manager, Engineering Department, inventors in patent 2,797,764 for a hydraulic steering assembly with motor forming one link of the assembly.

• **Robert M. Gold**, no longer with GM; **C. W. Lincoln***; and **Henry S. Smith**, (*B.S., Central Michigan College, 1938* and *M.S., University of Michigan, 1940*) administrative engineer, Product Engineering Department, inventors in patent 2,798,461 for fluid power steering.

• **C. W. Lincoln***, **Joseph J. Verbrugge***, and **Philip B. Zeigler*** inventors in patent 2,800,801 for an in-line hydraulic power steering gear.

GM Styling Staff Detroit, Michigan

• **William Hess**, (*M.E. diploma, Drexel Institute, 1921*) chief engineer—automotive interiors, Interior Engineering (Automotive); **Rudolph Potocnik**, chief engineer, Body Development Studio; and **Frederick C. Walther**, retired, inventors in patent 2,793,907 for a vertically swingable station wagon tail-gate with retractable window.

• **Harley J. Earl**, (*Stanford University*) vice president in charge of Styling Staff, inventor in patent 2,795,455 for a tilted

seat-back window operating means for two-door vehicles.

• **Stefan Habsburg Lothringen**, (*B.S.M.E., Massachusetts Institute of Technology, 1955*) senior designer, Research "A" Studio, and **Clark E. Quinn**, research engineer, Physics and Instrumentation Department, GM Research Staff, inventors in patent 2,795,772 for a vehicle retractable lamp.

• **Robert F. McLean**, (*B.S.M.E., 1943* and *professional degree in industrial design, 1948, California Institute of Technology*) executive in charge of styling product analysis and planning, Administration Department, and **Robert Schilling**, (*M.E. degree, Technical University, Munich, Germany, 1922*) chief engineer, Research and Development, Chevrolet Motor Division, inventors in patent 2,797,951 for an aerodynamic brake for motor vehicles.

• **Edward G. Podolan**, (*Lawrence Institute of Technology*) senior project engineer, Exterior Engineering, inventor in patent 2,797,958 for an abutting front and rear door window seal construction for hard top sedan.

• **John Himka**, (*Diploma, Aero.E., Academy of Aeronautics, 1941*) general supervisor-in-charge body layout, Body Development Studio, inventor in patent 2,798,761 for a window regulator.

• **William A. Belfry**, senior layout man, Body Development Studio, inventor in patent 2,800,067 for a cowl ventilator.

Oldsmobile Division Lansing, Michigan

• **Ralph J. Duckworth**, (*Michigan State University*) transmission engineer, Product Engineering Department, inventor in

patent 2,791,894 for an anti-friction joint.

• **Henry C. Hoffman**, (*B.S.I.E., General Motors Institute, 1947*) supervisor, methods and layout, forge plant, inventor in patent 2,792,625 for a ring assembly machine.

• **Albert D. Baker**, (*B.S.M.E., Purdue University, 1926*) heating, cooling, and ventilating engineer, Product Engineering Department and **William E. Brown**, staff engineer, Delco-Remy Division, inventors in patent 2,798,906 for an indicator switch.

Ternstedt Division Detroit, Michigan

• **John C. Zerwick**, director, production engineering, Production Engineering Department, inventor in patent 2,795,979 for a chatterless countersink cutter.

• **Akira Tanaka**, (*B.S.M.E., Michigan State University, 1949*) group leader, design, Product Development Department and **Merril K. Lyon**, no longer with GM, inventors in patent 2,796,113 for a seat adjuster mechanism.

• **Samuel F. Loria**, (*B.S.M.E., Detroit Institute of Technology, 1939*) chief draftsman, Product Development Department, inventor in patent 2,797,431 for a door check and holdopen.

• **William B. Clark**, senior design engineer, Product Development Department, inventor in patent 2,798,532 for a seat adjuster.

• **LaVerne B. Ragsdale**, (*University of Detroit, Franklin College, and B.S.M.E., Lawrence Institute of Technology, 1939*) staff engineer, Product Development Department, inventor in patents 2,799,889 and 2,799,891 for a hinge holdopen and a deck lid counter-balance and holdopen.

Progress Under Patent System Told in Public Exhibit



Fig. 1— The Saginaw Steering Gear display used in a recent U. S. Department of Commerce exhibit was divided into three sections showing three patents in the field of power steering and actuator components (left), some typical non-automotive applications of these components (center), and a demonstration of the advantages of power steering over manual steering (right).

“RESEARCH and Progress in the Mechanical Field Under the American Patent System” was the theme of a public exhibit held recently in the U. S. Department of Commerce Building, Washington, D. C. The purpose of the exhibit was to dramatize the story of American industrial progress in the mechanical field made possible in a large measure by our country’s patent system. Various examples of mechanical developments were shown by means of displays furnished by American firms.

One space in the exhibit was allotted to General Motors for a display developed by Saginaw Steering Gear Division. The display (Fig. 1) dramatized how three patents relating to power steering and hydraulic actuators have been utilized in various automotive and non-automotive applications.

Illustrations of the patent grants were shown together with photographs depicting some typical non-automotive applications of these components in agricultural and industrial vehicles, earthmoving machines, and aircraft. Also shown was

a cut-away power steering mechanism with its integral mechanical and hydraulic components, a ball bearing screw, and a ball bearing spline.

The ball bearing screw and spline shown were of the type used for aircraft application. The ball bearing screw is used, for example, to actuate such aircraft components as landing gear mechanisms and control surfaces. The ball bearing spline is used for torque restraint application. Such an application is made on an aircraft oleo strut to allow easy relative movement of the member while the overall assembly is under high torque or bending moment.

An automotive application was illustrated by a demonstration showing the advantages of power steering over manual steering. A visitor to the display stood on a step supported by two hand rails. When a switch was moved to the left the steering system was set for manual

steering and by turning the steering wheel the visitor could lower or raise himself. When the switch was moved to the right the steering system was set for power steering. When the steering wheel was turned the visitor again could raise and lower himself but this time was aware of the minimum effort required to turn the wheel. The demonstration showed effectively the ease of power steering.

Each year, similar exhibits are held at the Commerce Building featuring developments in the electrical and chemical fields.

The patent system as established in the Constitution deserves and has received considerable credit for the development of American industry. It is the purpose of these exhibits sponsored by the U. S. Department of Commerce to graphically demonstrate ways in which patents have abetted industrial growth.

Solution to the Previous Problem:

Determine the Operating Characteristics of a Drive and Control System for a Transfer Mechanism

To power and control a crank and connecting rod transfer mechanism used for an automatic assembly machine, engineers of the GM Process Development Staff selected an electric motor to drive a speed reducer through a conventional truck clutch and a brake. Before the overall design of the drive and control system could be finalized, however, it was necessary to calculate its operating characteristics and determine whether the system was operating near critical conditions. Calculations made indicated that the minimum motor speed resulting from clutch engagement was 1,690 rpm, which was well above the minimum allowable speed, and that the clutch slip was approximately $\frac{1}{8}$ revolutions per engagement. The output shaft of the speed reducer was found to rotate approximately $8\frac{1}{2}^\circ$ between the time of engagement and before the system regained its required speed. This resulted in a lost index time of about 0.013 seconds. Calculations made regarding the expected life of the clutch showed that the heat generated at the clutch face at each engagement was approximately 0.8 Btu. This is the solution to the problem presented in the October-November-December 1957 issue of the GENERAL MOTORS ENGINEERING JOURNAL.

THE first step is to determine the moment of inertia I_1 of the clutch input. This may be found by adding together the moments of inertia of the motor, the clutch section attached directly to the output shaft of the motor, and the constantly rotating coupling as follows:

$$I_1 = 0.178 + 0.375 + 0.007 \\ = 0.560 \text{ slug-ft}^2.$$

When the clutch is engaged the net torque applied to the input shaft of the clutch is the difference between the motor torque N_m and the clutch coupling torque N_c (Fig. 1). The dynamic equation of the clutch input shaft, therefore, can be written as follows:

$$N_m - N_c = I_1 \left(\frac{d\omega_1}{dt} \right) \quad (1)$$

where

ω_1 = angular velocity of the clutch input shaft (radians per sec)

$\frac{d\omega_1}{dt}$ = angular acceleration of the clutch input shaft (radians per sec²)

$I_1 \left(\frac{d\omega_1}{dt} \right)$ = inertial torque of the clutch input (lb-ft).

Substituting into equation (1) the known values for N_m , N_c , and I_1 and

solving for $d\omega_1/dt$ gives the following value for the angular acceleration:

$$\frac{d\omega_1}{dt} = \frac{N_m - N_c}{I_1} \\ \frac{d\omega_1}{dt} = \frac{60 - 300}{0.56} = -429 \text{ radians per sec}^2.$$

The moment of inertia I_2 of the clutch output can be calculated by adding together the inertia of the masses attached to the output shaft as follows:

$$I_2 = 0.013 + 0.01 + 0.006 + \frac{20.8}{(102)^2} \\ I_2 = 0.031 \text{ slug-ft}^2.$$

When the clutch is engaged the net torque applied to the clutch output shaft is the difference between the clutch coupling torque N_c and the frictional torque N_f of the speed reducer (Fig. 2). The dynamic equation of the clutch output shaft, therefore, can be written as follows:

$$N_c - N_f = I_2 \left(\frac{d\omega_2}{dt} \right) \quad (2)$$

where

ω_2 = angular velocity of clutch output of shaft (radians per sec)

$\frac{d\omega_2}{dt}$ = angular acceleration of clutch output shaft (radians per sec²)

$I_2 \left(\frac{d\omega_2}{dt} \right)$ = inertial torque of clutch output (lb-ft).



The efficiency of the speed reducer was stated as 81 per cent. The friction torque N_f of the speed reducer, therefore, can be determined as follows:

$$N_f = 0.19 (N_c) \\ N_f = 0.19 (300) = 57 \text{ lb-ft.}$$

Substituting the known values for N_f , N_c , and I_2 into equation (2) and solving for $d\omega_2/dt$ gives the following value for the angular acceleration of the clutch output shaft:

$$\frac{d\omega_2}{dt} = \frac{N_c - N_f}{I_2} \\ \frac{d\omega_2}{dt} = \frac{243}{0.031} = 7,840 \text{ radians per sec}^2.$$

When the angular velocity ω_1 of the input shaft of the clutch equals the angular velocity ω_2 of the output shaft no slippage will occur. The speed of the motor when the clutch is disengaged was set at 1,790 rpm. The initial angular velocity of the input shaft, therefore, can be calculated as follows:

$$\omega_1 (\text{initial}) = \frac{(1,790) (2\pi)}{60} \\ = 187 \text{ radians per sec.}$$

When the clutch is engaged there is a certain amount of slippage time T_s which takes place. This slippage time can be expressed by the following relationship:

$$\omega_1 (\text{initial}) + \frac{d\omega_1}{dt} (T_s) = \frac{d\omega_2}{dt} (T_s). \quad (3)$$

Substituting into equation (3) the known values for the initial angular velocity of

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General Motors Process
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Assisted by Gerhard W. Sood
General Motors Institute

Preliminary calculations

show that proposed design

will perform as desired

the input shaft and the angular accelerations of the input shaft and the output shaft gives the following value for the clutch slippage time:

$$187 - 429 (T_s) = 7,849 T_s$$

$$T_s = 0.0226 \text{ seconds.}$$

Knowing the clutch slippage time, the minimum motor speed (ω_1 minimum) resulting when the clutch is engaged can be calculated as follows:

$$\omega_1 (\text{minimum}) = \omega_1 (\text{initial}) + \frac{d\omega_1}{dt} (T_s)$$

$$\omega_1 (\text{minimum}) = 187 - 429 (0.0226)$$

$$\omega_1 (\text{minimum}) = 177 \text{ radians per sec}$$

$$\omega_1 (\text{minimum}) = 1,690 \text{ rpm.}$$

The angle Θ_1 rotated by the input shaft of the clutch during slippage can be calculated as the product of the average angular velocity of the input shaft and the slippage time T_s :

$$\Theta_1 = \omega_1 (\text{average}) \times T_s$$

$$\Theta_1 = 182 (0.0226) = 4.1 \text{ radians.}$$

The angle Θ_2 rotated by the output shaft during slippage can be calculated as follows:

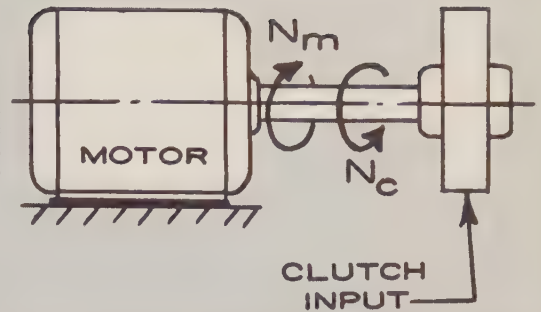
$$\Theta_2 = \frac{1}{2} \left(\frac{d\omega_2}{dt} \right) (T_s)^2$$

$$\Theta_2 = \frac{1}{2} (7,840) (0.0226)^2$$

$$\Theta_2 = 2.0 \text{ radians.}$$

The angle of the clutch slippage is equal to $\Theta_1 - \Theta_2$ or 2.1 radians. The number of revolutions the clutch slips

Fig. 1—This diagram illustrates the direction of the motor torque N_m and the clutch coupling torque N_c . When the clutch is engaged the net torque applied to the clutch input shaft is the difference between these two torques.



with every engagement, therefore, is equal to 2.1 radians divided by 6.28 radians per revolution or 0.33 revolutions.

The normal operating speed of the motor, under load and after clutch engagement, was stated as 1,750 rpm, or 183 radians per second. The time required for the motor to accelerate from 1,690 rpm to 1,750 rpm can be calculated as follows:

$$N_m - 0.19 (N_m) = I_{total} \left(\frac{d\omega}{dt} \right) \quad (4)$$

where

$$I_{total} = I_1 + I_2$$

$\frac{d\omega}{dt}$ = angular acceleration of the overall drive and control system (radians per sec²).

Substituting into equation (4) the known values for N_m and I_{total} gives the following value for the angular acceleration of the overall system:

$$\frac{d\omega}{dt} = \frac{N_m - 0.19 (N_m)}{I_{total}}$$

$$\frac{d\omega}{dt} = \frac{48.6}{0.591} = 82.5 \text{ radians per sec}^2.$$

The calculated value for the angular acceleration of the overall system can be used to calculate the time T_r required for the motor to accelerate to the normal operating speed as follows:

$$T_r = \frac{\omega (\text{final}) - \omega (\text{start})}{\frac{d\omega}{dt}}$$

$$T_r = \frac{183 - 177}{82.5} = 0.073 \text{ seconds.}$$

The total time T_t required to regain normal operating speed from the time of clutch engagement is equal to $T_s + T_r$ or 0.0956 seconds.

If the motor had been rotating at 1,750 rpm the output shaft would have rotated through $183(0.0956)$ or 17.5 radians. The average speed of the output shaft during the time T_r that the shaft accelerated to the normal operating speed was 180 radians per second. During the time T_t , therefore, that the output shaft was accelerating to normal operating speed the output shaft actually rotated through $2.0 + 180(0.073)$ or 15.2 radians.

The time lost T_t compared to a con-

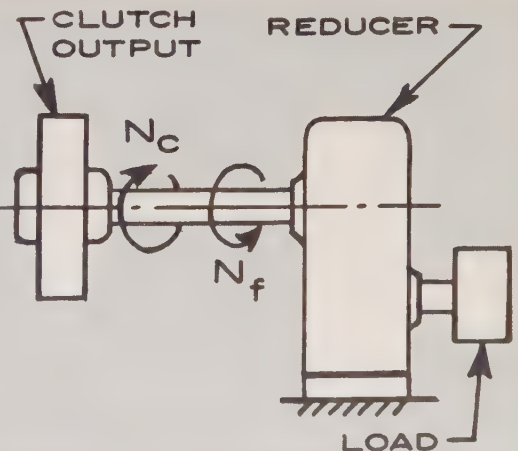


Fig. 2—The net torque applied to the clutch output shaft, when the clutch is engaged, is the difference between the clutch coupling torque N_c and the frictional torque N_f of the speed reducer.

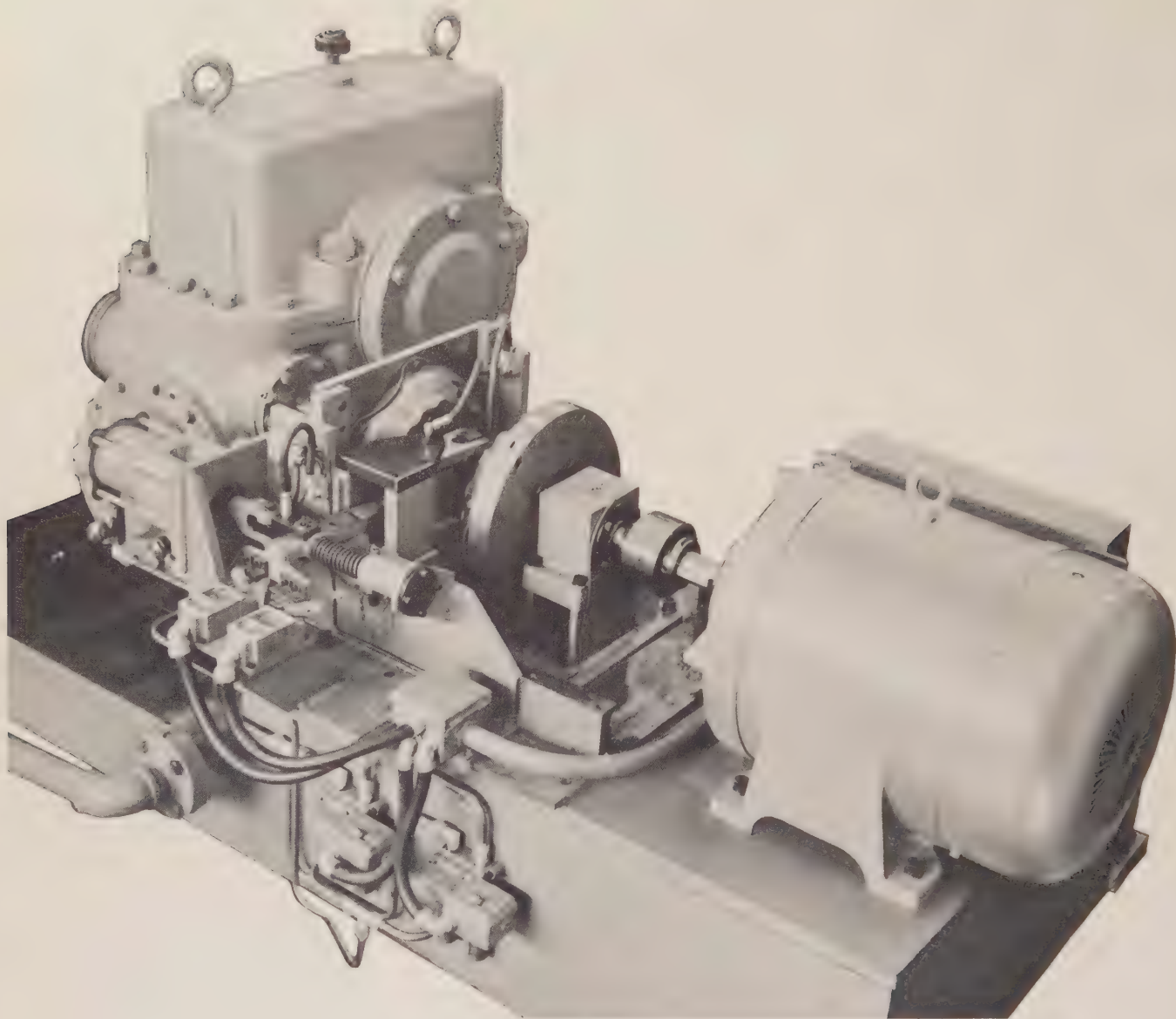


Fig. 3—The dual drive and control system was used on an automatic assembly machine to assemble automotive cylinder heads. A 20 hp motor drives a speed

reducer through a conventional truck clutch. A second clutch is used as a brake. For clarity, safety guards were removed when this picture was taken.

stant motor speed of 1,750 rpm can be calculated as follows:

$$T_l = \frac{17.5 - 15.2}{183} = 0.0126 \text{ seconds.}$$

The output shaft rotation Θ_r of the speed reducer before the motor speed is back to 1,750 rpm equals:

$$\Theta_r = \frac{(15.2)(57.29)}{102}$$

$$\Theta_r = 8.55 \text{ degrees.}$$

The heat generated H_e at the clutch face can be calculated as follows:

$$H_e = N_e (\Theta_1 - \Theta_2)$$

$$H_e = 300 (2.1) = 630 \text{ lb-ft}$$

$$H_e = \frac{630 \text{ lb-ft}}{778 \text{ lb-ft per Btu}} = 0.81 \text{ Btu.}$$

Summary

The preceding calculations are valuable to the engineer in demonstrating that it is now possible to evaluate the transfer mechanism with respect to such

governing factors as clutch wear, lost time, and motor speeds. As a result of the calculations the engineer can proceed to the construction phase of the project with considerable assurance that the proposed transfer mechanism and its drive and control unit will perform as desired. A drive and control system of the type described was adopted for use on an automatic assembly machine (Fig. 3). The predicted results were borne out when the system was installed and placed in operation.

Technical Presentations by GM Engineers

The technical presentation is another way in which information about current engineering and scientific developments in General Motors can be made available to the public. A listing of speaking appearances by General Motors engineers, such as that given below, usually includes the presentation of papers before professional societies, lecturing to college engineering classes or student societies, and speaking to civic or governmental organizations. Educators who wish assistance in obtaining the services of GM engineers to speak to student groups may write to the Educational Relations Section, Public Relations Staff, General Motors Technical Center, P. O. Box 177, North End Station, Detroit 2, Michigan.

GM personnel who have made recent presentations are as follows:

Automotive Engineering

Howard H. Dietrich, senior research and experimental engineer, Product Engineering and Development Department, Rochester Products Division, before the Society of Automotive Engineers west coast meeting, Seattle, Washington, August 16; title: Automotive Exhaust Hydrocarbon Reduction During Deceleration by Induction System Devices.

Before the S.A.E. west coast meeting, Seattle, August 16, GM Research Staff Fuels and Lubricants Department speakers: **F. W. Bowditch** and **W. M. Wiese**, senior research engineers; title: How to Recognize Unnecessary Vehicle Exhaust Smoke Emissions. **G. J. Nebel**, senior research engineer; title: Automobile Exhaust Gas Treatment—an Industry Report.

Tom R. Tompkins, experimental engineer, Product Engineering Department, Oldsmobile Division, before the Junior Chamber of Commerce, Ionia, Michigan, September 10; title: What Oldsmobile Does at the GM Proving Ground, and before the Kiwanis Club, Alma, Michigan, September 25; title: Oldsmobile Experimental Engineering and Proving Ground Facilities.

Vaughn H. Hardy, chief engineer, Delco Appliance Division, before the Detroit Section S.A.E. meeting, White Sulphur Springs, West Virginia, September 13; title: Trends in Electrical Power Assists for Automated Automobiles.

S. L. Milliken, future development supervisor, Engineering Department, Cadillac Motor Car Division, before the University of Detroit Student Chapter of the S.A.E., Detroit, September 18; title: Cadillac Eldorado Brougham Air Suspension, and before the S.A.E. Sectional Meeting, Muskegon, Michigan, November 5; title: Cadillac's Air Suspension.

William H. Jackson, senior project engineer, Air Conditioning Section, Product Engineering Department, Harrison Radiator Division, before the Connecticut Section of the American Society of Heating and Air Conditioning Engineers, New Haven, September 19; title: Recent Developments in Automotive Air Conditioning.

Robert R. Mandy, supervising engineer, Air Conditioning Section, Product Engineering Department, Harrison Radiator Division, before the Niagara Falls, New York Rotary Club, September 23; title: Automotive Air Conditioning.

Shirrell C. Richey, staff engineer, Electrical and Accessories Group, Chevrolet Motor Division, before the Community Congregational Church, Lathrup Village, Michigan, September 27; title: A Carriage for Milady.

Harold Drew, chief engineer, GM Overseas Operations Division, before the S.A.E. Mid-Michigan Section, Lansing, October 7; title: Small Cars—Pros and Cons.

L. M. Forbush, assistant engineer-in-charge, Automotive Ordnance Section, GM Engineering Staff, before the Mohawk-Hudson, New York section of the S.A.E., October 8; title: Automotive Design Trends.

Rex W. Oyler, assistant chief engineer, Product Engineering Department, Guide Lamp Division, before a meeting of Anderson, Indiana school teachers in connection with Business-Industry-Education Days, August 29 and September 5, and before the Anderson Exchange Club, October 8; title: The Improved Night Driving Safety with the Four-Headlamp System.

A. F. Underwood, manager, GM Research Staff activities, before the Societe Des Ingenieurs de L'Automobile, Paris, October 10; title: Le XP 500 avec Moteur a Pistons Libres.

Robert L. Barager, junior engineer, Product Service Department, Rochester Products Division, before the Rotary Club, Lima, New York, October 10; title: Fuel Injection.

D. E. Brinkerhoff, senior project engineer, Engineering Department, Delco Radio Division, before the Audio Engineering Society, New York City, October 12; title: Some Observations on Reproduced Sound in an Automobile.

Paul C. Skeels, head, Experimental Engineering Department, GM Proving Ground, before the Detroit Section of the Instrument Society of America, October 17; title: Automotive Proving Ground Instrumentation.

Before the National Conference on Industrial Hydraulics, Chicago, October 17, Chevrolet Motor Division speakers: **Robert W. Graham**, design engineer, Research and Development, and **Ronald E. Shafer**, junior engineer, Test Laboratory; title: Servo-Controlled Simulator for Measurement of Ride and Control Characteristics on Automotive Vehicles.

F. L. Mackin, chairman, Machine and Woodshop, General Motors Institute, before the National Conference on Industrial Hydraulics, Chicago, October 18, moderator of panel on Fuel Injection and Servo Mechanisms for Control of Speed of Accessories.

Charles J. Griswold, Jr., senior project engineer, Design and Drafting Department, Fisher Body Division, before the American Society of Body Engineers, Detroit, October 23; title: The Eldorado Brougham.

George A. Brown, field engineer, Spark Plug Engineering Department, AC Spark Plug Division, before personnel of a Michigan trucking concern, Saginaw, October 9 and Pontiac, October 28; title: The Importance of Proper Selection

and Care of Spark Plugs in Fleet Operation.

William C. Cole, section engineer, Aircraft Spark Plug Engineering Department, AC Spark Plug Division, before commercial aircraft personnel, Houston, Texas; Shreveport, Louisiana; and Dallas, Texas; October 21-25; title: Aircraft Spark Plugs.

B. A. Schwarz, technical assistant to general manager, Delco Radio Division, before Acoustical Society of America, University of Michigan, Ann Arbor, October 25; title: Some Observations on Reproduced Sound in an Automobile.

Donald Stoltman, senior project engineer, Research and Development Department, Rochester Products Division, before the National Conference on Industrial Hydraulics, Chicago, October 18; title: An Analysis of Fuel Injection for Passenger Cars and before the Seneca Falls, New York Technology Club, October 1, the University of Wisconsin Student Chapter of the S.A.E., Madison, October 23, and the Cornell University Student Chapter of the S.A.E., Ithaca, New York, November 5; title: Fuel Injection.

John M. Campbell, scientific director, GM Research Staff, before the S.A.E. (Horning Memorial Lecture), Cleveland, November 7; title: Looking Ahead in Fuels for Automotive Transportation.

Donald J. LaBelle, staff engineer, Truck Engineering Department, GMC Truck and Coach Division, before the S.A.E. national transportation meeting, Cleveland, November 11; title: New Commercial Vehicle Concepts Possible with Air Suspension.

A. H. Kelly, assistant head, Experimental Engineering Department, GM Proving Ground, before the eastern New York section of Instrument Society of America, Schenectady, November 12; title: Automotive Proving Ground Instrumentation.

Bearings and Lubrication

Heinz Hanau, supervisor, aircraft projects, Product Engineering Department, New Departure Division, before engineering personnel of the Curtiss-Wright Corporation, Caldwell, New Jersey, August 20; title: Ball Bearings for Medium Speed, Very High Temperature Applications and before the Lear Continental

Symposium, Grand Rapids, Michigan, October 7-9; title: Ball Bearings for Very High Temperatures, and Ball Bearings for Gas Turbine Engines, respectively.

M. E. Otterbein, manager, Research and Development Department, Hyatt Bearings Division, before the A.S.M.E.-A.S.L.E. Lubrication Conference, Toronto, Canada, October 8; title: The Effect of Aircraft Gas Turbine Oils on Roller Bearing Fatigue Life.

R. J. Valentine, aircraft project engineer, Product Engineering Department, New Departure Division, before the Lear Continental Symposium, Grand Rapids, Michigan, October 9; title: High Temperature Bearings for Accessory Drives.

N. A. Hunstad, assistant head, Fuels and Lubricants Department, GM Research Staff, before the National Petroleum Association, Atlantic City, September 12; title: General Motors Views Rear Axle Lubricants.

F. G. Rounds, senior research engineer, Fuels and Lubricants Department, GM Research Staff, before the S.A.E., Cleveland, November 7; title: Coking Tendencies of Lubricating Oils.

Electrical Engineering

C. R. Knowlton, eastern zone manager, Sales Department, Delco Products Division, before the Belle Meade, New Jersey Rotary Club, September 15; title: Amateur Radio Hobby.

Bert H. Hefner, electrical engineer, Engineering Department, Electro-Motive Division, before the A.S.M.E.—Petroleum Industry Branch, Tulsa, Oklahoma, September 24; title: Advances in Diesel Electric Rig Design for Oil Well Drilling.

Joseph M. Biedenbach, **Roy W. Totten**, and **Merton A. Jacobs**, faculty members, Science Department, General Motors Institute, before the Flint Technical High School Science Club, Flint, October 22; titles: Shielding of Alpha, Beta, and Gamma Rays; Magnetic Fields and Methods of Inducing Electromotive Force; and Principles of the Cathode Ray Oscilloscope, respectively.

Foundry

C. E. Fausel, manufacturing superintendent, Central Foundry Division, before engineering students of the Uni-

versity of Illinois, Chicago, September 23; title: Opportunities in the Foundry Industry.

L. J. Pedicini, staff engineer, Foundry, Process Development Section, GM Process Development Staff, before the American Foundrymen's Society, Battle Creek, Michigan, September 25; title: Control of Quality in the Foundry.

C. E. Drury, manager, Danville, Illinois, plant of Central Foundry Division, before the A.F.S. regional conference, Rolla, Missouri, September 27; title: Gating to Control the Pouring Rate and Its Effect on the Casting.

Carl F. Schaefer, supervisor, Research Department, AC Spark Plug Division, before the American Ceramic Society, San Francisco, October 18; title: Compression, Injection, and Isostatic Molding of Alumina Ceramics.

E. E. Braun, works manager, Central Foundry Division, before the M.F.S. sales engineering clinic, Chicago, October 24; title: Tolerances.

Manufacturing

Harold Huddleston, methods engineer, Standards Department, Moraine Products Division, before the Dayton chapter of the A.S.T.E., August 21; title: Automation, an Economic Necessity.

Jack M. Beamish, elastomer engineer, Engineering Department, Detroit Transmission Division, before engineers of the Victor Manufacturing and Gasket Company, Chicago, September 17; title: Close Tolerance Dimension Required on 1958 Front Rotating Shaft Seal.

John M. Duncan, supervisor, Work Standards Section, GM Process Development Staff, before the Society for Advancement of Management, Detroit, October 10; title: Analyzing the Activities of Work Standards Personnel.

W. F. Diehl, senior project engineer, Process Development Section, GM Process Development Staff, before engineering students of Wayne State University, Detroit, October 21; title: Hydraulics for Manufacturing, and before the National Fluid Power Association, Washington, D. C., October 25; title: Hydraulic Fluids from the Users Viewpoint.

B. Moran, junior project engineer, Process Development Section, GM Process Development Staff, before engineering students of Wayne State University,

Detroit, October 21; title: Pump Slurry System.

W. A. Crickmore, supervisor, plant layout and **R. H. Mooney, Jr.**, senior methods engineer, Methods and Layout Department, Oldsmobile Division, before the National Safety Congress, Chicago, October 24; title: How to Design Safety into New Equipment.

Robert Guy, lubrication engineer, Master Mechanic Department, Detroit Transmission Division, before engineering students of Wayne State University, Detroit, October 26; title: Cutting Fluids.

William B. Scott, supervisor, Standards Department, Detroit Transmission Division, before the Material Utilization Central Committee, Cleveland, October 30; title: Material Methods Program at Detroit Transmission Division.

John F. Cantalin, engineer-in-charge, Electrical and Hydraulic Department, Fisher Body Division, before the American Welding Society, Detroit Section, October 24, and the A.W.S. Toledo, Ohio Section November 19; title: Resistance Welding in Automobile Body Production.

L. B. Ragsdale, staff engineer, Product Engineering Department, Ternstedt Division, before the American Society of Body Engineers, Detroit, October 25; title: Die Casting for Automotive Use.

Metallurgy

C. E. Norton, chief metallurgist, Metallurgical Department, New Department Division, before engineers of the Allegheny Ludlum Steel Company, Watervliet, New York, July 16; title: Use of Vacuum Melted Materials in Ball Bearings, and before engineers of the Vickers Corporation, Detroit, October 9; title: Metallurgy of High Temperature Ball Bearings.

R. F. Thomson, head, Metallurgical Engineering Department, GM Research Staff, before the American Society for Metals, Detroit, October 14; title: Are Metallurgists Prepared for 19XX?

Before the American Society for Testing Materials, Detroit, October 23, GM Research Staff Physics and Instrumentation Department speakers: **W. L. Grube**, supervisor, **S. R. Rouze**, senior research physicist, and **T. R. McKinney**, senior physics technician; title: Electron Metal-

lographic Study of Pearlite, Bainite, and Tempered Martensite in S.A.E. 4140 Steel.

Before the American Society for Metals, Chicago, November 4, GM Research Staff Physics and Instrumentation Department speakers: **Donald P. Koistinen**, research physicist; title: The Influence of Phase Composition on the Residual Stress Distribution in Carburized Cases on Various Steels; **S. R. Rouze**, senior research physicist, and **W. L. Grube**, supervisor; title: Electron Metallographic Study of Carburized and Carbonitrided Cases.

Miscellaneous Subjects

Wallace E. Wilson, general manager, Rochester Products Division, before the General Motors Institute Technical Club, Rochester, New York, August 27; title: What is the Future for the Young Engineer, and before the Rochester Chamber of Commerce, September 23; title: The Importance of Your Chamber of Commerce Membership.

Byron H. Holmes, assistant chief engineer, Chevrolet Motor Division, before the Conference on Utilization of Scientists and Engineers, West Virginia University, Charleston, September 5; title: On-the-Job Training Programs Pay Big Dividends.

John S. Wolfe, chemist, research and development, Engineering Department, Delco Products Division, before the American Chemical Society national meeting, New York City, September 9; title: Spectroanalysis as an Adjunct in Water Analysis Problems.

George J. Pollard, assistant in charge, Automobile Interiors and Color Studio, GM Styling Staff, before the Midwest College Placement Association, Detroit, September 17; title: Today's Designers.

Peter Wallack, assistant chief engineer, Product Engineering Department, New Departure Division, before the A.S.M.E. fall meeting, Hartford, Connecticut, September 23; title: Professional Development Through Continued Education.

John C. White, Jr., senior project engineer, Material Testing Laboratory, Fisher Body Division, before the Detroit Rubber and Plastics Group, Detroit, October 4; title: Vinyl and Mylar Materials.

Leon DeMause, administrative engineer, Engineering Department, Cadillac

Motor Car Division and **R. P. Trowbridge**, head, GM Engineering Standards Section, before the American-British-Canadian Conference on the Unification of Drawing Practices, Toronto, Canada, October 7-10; title: Areas of Agreement and Disagreement in the Drawing Standards of the United States, Great Britain, and Canada.

George E. Hodgins, plant engineer, Plant Engineering Department, GM Proving Ground, before the Illinois Association of Highway Engineers, Peoria, October 12; title: The General Motors Proving Ground and Proving Ground Roads.

Donald C. Perkins, body engineer, Product Engineering Department, Oldsmobile Division, over station WKAR-TV, East Lansing, Michigan, October 16; title: Insight into Industry.

J. R. Thomson, process engineer, Process Engineering Laboratory, Oldsmobile Division, before the Kiwanis Club, Holt, Michigan, October 29; title: Industrial Chemistry at Oldsmobile.

Alan S. McClimon, manager, Sales Development Department, Euclid Division, before American Public Works Association, Los Angeles, November 7; title: More Highways per Dollar with Modern Earthmovers.

Research

G. J. Nebel, senior research engineer and **M. W. Jackson**, research engineer, Fuels and Lubricants Department, GM Research Staff, before the American Chemical Society, New York City, September 13; title: Some Factors Affecting the Concentration of Oxides of Nitrogen in Exhaust Gases from Spark Ignition Engines.

Before the American Nuclear Society, New York City, October 28, GM Research Staff Nuclear Power Engineering Department speakers: **A. Foderaro**, senior nuclear physicist; title: Transverse Leakage Specification in Multigroup Pseudo One-Dimensional Problems; **H. L. Garabedian**, assistant head, and **P. von Herrmann**, senior nuclear physicist; title: Reactor Kinetics for Multi-Region, Multi-Fuel Reactors; **F. E. Jablonski**, senior research physicist, and **R. S. Carter**, Westinghouse Research Laboratories; title: A Study of Split Cores for Research Reactors.

*Solution to the Previous General
Motors Institute Laboratory Problem:*

Determine the Center of Gravity Location of a Passenger Car



One approach to determine experimentally the center of gravity location in a passenger car is to balance the car on a knife edge test fixture. This supplies data used to obtain the height of the center of gravity above ground level. Data obtained from scale load readings of each wheel of the car plus a measurement of its wheelbase and wheel tread provide information for determining the center of gravity in the fore and aft and lateral positions. This is the solution to the problem presented in the October-November-December 1957 issue of the *GENERAL MOTORS ENGINEERING JOURNAL*. The height of the center of gravity above ground level is *21.13 in.* In the fore and aft direction, the center of gravity is *56.09 in.* behind the centerline of the front wheels. The lateral center of gravity is *0.52 in.* to the left of the longitudinal centerline of the car.

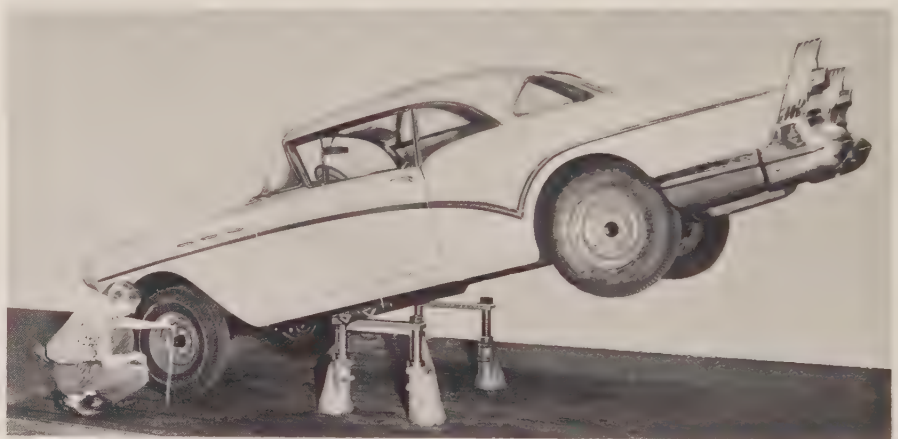
WHEN using the knife edge test fixture to locate the height of the center of gravity above ground level, it is important to locate the fixture so that the center of gravity lies somewhere between the two knife edges. If the center of gravity were to lie outside the knife edge supports only one balance point could be found, since the knife edge closest to the center of gravity would not yield a balance point.

To obtain maximum accuracy when determining the height location of the center of gravity, both the front and rear suspension systems were locked in place before the car was elevated and balanced on the knife edges. This allowed the suspensions to remain in the same position as at normal ground height and prevented any shift of the unsprung weight when the car was elevated. Since the car was tipped both forward and rearward on the knife edges the effect of gasoline, oil, and engine coolant weight shifts partially cancelled out.

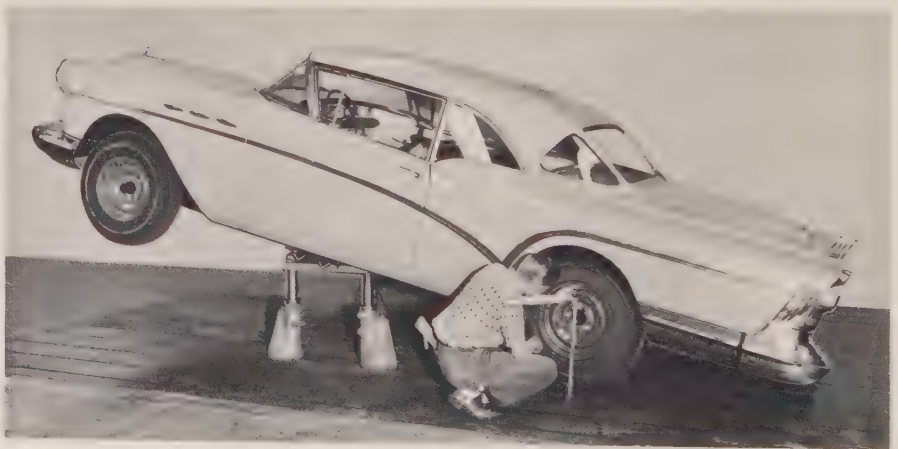
The first step in the solution to the problem is to determine the longitudinal center of gravity location. The total weight of the car is 4,300 lb and the total weight at the right and left rear wheels is 1,977 lb. A summation of moments about the centerline of the front wheels gives the following value for x , the location of the longitudinal center of gravity:

$$4,300 (x) = 1,977 (122)$$

$$x = 56.09 \text{ in. to the rear of the centerline of the front wheels.}$$



a



b

Fig. 1—In the General Motors Institute mechanical engineering laboratory the height of the center of gravity of a passenger car is determined with the aid of a knife edge test fixture. This fixture consists of two angle irons welded to a steel plate which is fastened to the frame of the car. The car is first tipped forward (a) and then rearward (b) on the knife edges to establish balance, or null, points. At each null point the height from the reference surface to the center of the wheels is measured. These measured distances are used to calculate the null point angles α and β for each balanced position. These angles, in turn, are used in the final calculation for determining the height of the center of gravity above ground level.

Faculty Member-in-Charge:

STEVE CENKO

G.M.I. Cooperative Students:

ROBERT H. BORCHERTS

Cadillac Motor Car Division

and RONALD J. SWANSON

Chevrolet Motor Division

Application of moment

summations and law of

cosines solved the problem

In a similar manner, a summation of moments about the centerline through the front and rear right wheels gives the following value for y , the location of the lateral center of gravity:

$$4,300 (y) = 2,188 (59.25)$$

$$y = 30.15 \text{ in. inward from the right wheels.}$$

To locate the lateral center of gravity with respect to the longitudinal centerline of the car, one half of the wheel tread width is subtracted from the above value for y . The location for the lateral center of gravity, therefore, is $30.15 - 29.63$, or 0.52 in. to the left of the longitudinal centerline of the car.

The distance from the reference surface to the center of the front and rear wheels, when the car is at the two balance positions (Fig. 1), can be used to determine the front null point angle α and the rear null point angle β as follows:

$$\sin \alpha = \frac{42.62 - 19.69}{122} = 0.18795$$

$$\alpha = 10.83^\circ$$

$$\sin \beta = \frac{42.81 - 15.50}{122} = 0.22385$$

$$\beta = 12.94^\circ$$

The establishment of null point angles α and β allows the construction of a triangle (Fig. 2) whose apex A corresponds to the location of the center of

CENTER OF GRAVITY

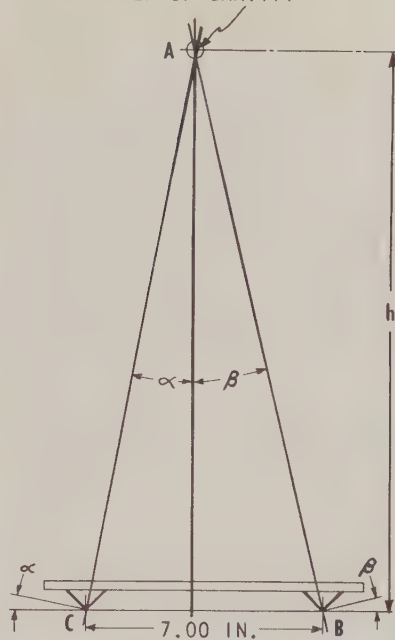


Fig. 2—Once the null point angles α and β are computed, the above triangle can be constructed to compute the height of the center of gravity. The distance h represents the height of the center of gravity above the knife edges. To this calculated height is added the distance from the knife edges to the ground to determine the overall height value.

gravity and whose height h corresponds to the height of the center of gravity above the knife edges. Side AB of the triangle can be calculated from the Law of Sines as follows:

$$\frac{AB}{\sin (90^\circ - \alpha)} = \frac{BC}{\sin (\alpha + \beta)}$$

$$BC = 7.00 \text{ in.}$$

Therefore,

$$AB = 7 \left[\frac{\sin (90^\circ - \alpha)}{\sin (\alpha + \beta)} \right]$$

$$AB = 17.06 \text{ in.}$$

The height of the center of gravity h is calculated as follows:

$$h = AB \cos \beta$$

$$h = 17.06 (0.97461)$$

$$h = 16.63 \text{ in.}$$

The distance from the knife edges to the ground level was recorded as 4.50 in. The height of the center of gravity above ground level, therefore, is equal to 16.63 in. + 4.50 in., or 21.13 in.

Student Contributors to the General Motors Institute Laboratory Problem

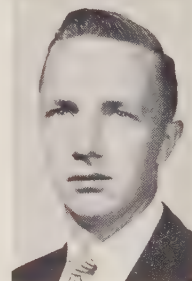
ROBERT H. BORCHERTS,



completed the Four-Year cooperative program in August of 1957 and presently is on an educational leave of absence from Cadillac Motor Car Division to do graduate work at the University of Michigan.

Mr. Borcherts joined Cadillac in 1953 as a G.M.I. co-op student. During the first two years of the cooperative program his plant assignments included work in the Foundry, Material Control, Plant Layout, and Cost Estimating Departments of Cadillac. His plant assignments during the third and fourth year of the program were in the Engineering Department where he gained experience in design, laboratory test work, and engineering specifications. Mr. Borcherts is a member of Alpha Tau Iota, honorary society, and the Society of Automotive Engineers.

RONALD J. SWANSON,



is a junior engineer at the Chevrolet Motor Division Engineering Center, Warren, Michigan. Mr. Swanson presently is participating in the G.M.I. Fifth Year Program which will qualify him for a

baccalaureate degree in mechanical engineering when completed. His assigned project study deals with a method for rating heavy-duty truck brakes on the basis of maximum continuous horsepower absorption. Mr. Swanson joined Chevrolet in 1953 as a G.M.I. co-op student. During the Four-Year cooperative program his plant work assignments were in the Drafting Department, Experimental Engineering Test Laboratory, and the Chevrolet engineering test facility located at the General Motors Proving Ground. Mr. Swanson is a member of Alpha Tau Iota, honorary society, and the Society of Automotive Engineers.

A Typical General Motors Institute Laboratory Problem:

Determine the Unbalanced Forces in a Converted V-8 Engine

A familiar sight in mechanical engineering laboratories, either school or industrial, is the single cylinder CFR engine. This engine provides a laboratory method for investigating knock ratings of gasoline and the effects of spark timing and compression ratio on engine performance. The CFR engine, however, has a limitation—versatility—especially when used for student laboratory work, where the time element is important. To provide a more versatile test engine, on which several different tests could be run with a minimum of changeover time between each test, the Product Engineering Department of General Motors Institute decided to take a stock V-8 engine and convert it to a four cylinder engine. This conversion was assigned as a laboratory project. To convert the V-8 engine it was necessary first to balance the engine for the new reciprocating and rotating masses. The principles used to determine the engine balance requirements were the same as those for any engine. However, the unusual aspects of this particular balancing problem provided an opportunity for a greater understanding of the basic principles involved.

THE single cylinder, Cooperative Fuel Research (CFR) Committee engine is used extensively for internal combustion engine testing and research work. This engine, originally designed for evaluating knock ratings of gasolines, also has been adapted to investigate the effects of compression ratio and spark timing on engine performance.

The CFR engine has certain limitations. One limitation, for example, is that only one test at a time can be run on the single cylinder engine. To run a test involving different combustion chamber configurations requires considerable set-up time. For a laboratory class period of specific time duration this can be a hindrance. Another limitation of the CFR engine is that it does not provide for current practices of breathing and combustion chamber volume distribution. These and other limitations of the CFR engine take away from its versatility as an ideal laboratory engine for student use.

At General Motors Institute data and conclusions obtained during mechanical engineering laboratory periods of the automotive engine course are used as background information for concurrent design classes. To make better use of the time element in a laboratory test period it is desirable to use an engine which can be set up to run several different tests

with a minimum of changeover time. The CFR engine does not provide entirely this desired feature. It was felt, therefore, that a need existed for developing a more versatile laboratory test engine which could be used to analyze such variables as combustion chamber configuration, valve arrangement, spark plug location, compression ratio, cooling, timing, and combustion phenomena.

An extensive investigation indicated that a basic stock engine would meet satisfactorily the need for a more versatile laboratory test engine with the minimum of expense and in the time necessary to obtain the desired test engine. To change the cylinder head of a stock engine for the purpose of using it for tests on different combustion chamber configurations and compression ratios would be an expensive proposition. It was known, however, that suppliers of pistons could cast a thick crown into an existing piston mold quite easily. Using blank pistons with additional metal on the dome would permit machining the piston to remove the excess metal and achieve any type of combustion chamber desired. This would allow various combustion chamber designs to be evaluated from the standpoint of peak pressure, rate of pressure rise, octane requirements, idle characteristics, fuel consumption,

and power output. Tests to investigate the effects of spark plug location could be made for short runs by using special plugs having extended electrodes.*

V-8 Engine Converted to Single Cylinder Test Engine

A Chevrolet V-8 engine was selected for conversion to a single cylinder test engine. The overall idea was to use a multi-cylinder engine but allow only the cylinder under test to fire. This would save set-up and changeover time. Each cylinder could be set up for a different test and the changeover accomplished in a few minutes by merely installing a fuel supply unit feeding only the intake port of the cylinder under test. The fuel supply could be by either a small carburetor or fuel injection unit.

To use the converted engine for combustion cycle analysis it was necessary to provide some type of pressure pickup to indicate pressures within the combustion chamber. Because of the compactness and valve arrangement of the Chevrolet V-8 engine only the four outer cylinders could be provided with pressure pickups. To make this provision, and also reduce engine friction to a minimum, the piston and rod assemblies from the middle four cylinders were removed.

There were, of course, many other considerations required before the converted engine would be able to perform the various tests contemplated. These considerations, however, do not apply directly to the problem at hand.

*Engineering educators interested in obtaining more information regarding the conversion of a stock engine for laboratory test work may write to General Motors Institute, Product Engineering Department, Chevrolet at Third, Flint, Michigan.

Solve an engine balance problem

created when 4 pistons are re-

moved from an 8-cylinder engine

- Reciprocating weight (piston less rings, piston pin, and small end of connecting rod) = $W = 1.90$ lb
- Engine speed = $N = 3,000$ rpm
- Stroke = 3 in.
- Cylinder center distance = $L = 4.4$ in.
- Bank angle = 90°
- One-half bank angle = $\alpha = 45^\circ$
- Angular displacement of number I crankpin from the vertical = Θ° (Θ is assumed to be 0°).

One of the first steps in determining the balancing forces involved concerns finding the weight and center of gravity of the cheeks, or counterweights, and

crankpins of the crankshaft. These values for the crankpins were determined from the crankshaft drawing. Because of the irregular configuration of the cheeks, however, determination of their weight and center of gravity was more difficult. A scrap production V-8 engine crankshaft was obtained and cut to obtain each cheek separately. The cheeks were then weighed and their center of gravity determined by placing them on knife edges in two planes. The center of gravity was determined by an approximation in the third plane—the plane of thickness of the cheek. After the weights for the cheeks and crankpins and the location

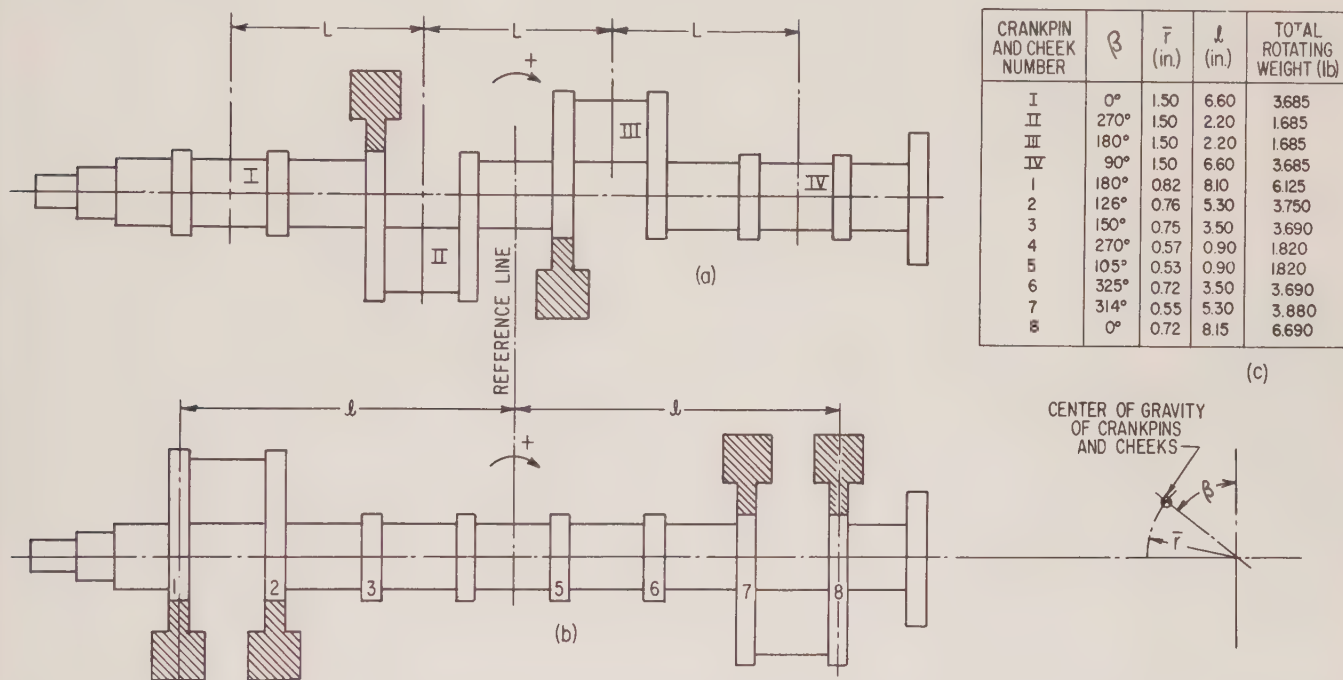


Fig. 1—The four middle cylinders of the V-8 engine had to be removed before the engine could be used as a four-cylinder laboratory test engine. This left only the four outer pistons and rods, located on crankpins I and IV. The location of crankpins I, II, III, IV is indicated in the plan view (a) of the crankshaft. The left side view of the crankshaft (b) shows the eight cheeks and counterweights. The cross-hatched areas represent the counterweights. In the drawings, β is the angle of center of gravity with respect to

the centerline of the number I crankpin, \bar{r} is the distance from the centerline of the crankshaft to the center of gravity location of the cheeks and crankpin, and l is the moment arm distance for the cheeks and crankpin. The distance between crankpin centerlines is designated as L , which is equal to 4.4 in. Also shown is the direction of positive moments. Shown in tabulated form (c) is the total rotating weight and center of gravity location for each of the crankpins and cheeks.

Problem

Removal of the middle four piston and rod assemblies from the V-8 engine disturbed the original static and dynamic balance. This gave rise to the problem presented here—determine the unbalanced forces in the converted engine and balance the engine.

The following data are pertinent to the solution of the problem:

- Rotating weight of connecting rod and cap = 1.00 lb

The problem presented here is typical of problems assigned to students enrolled in advanced laboratory course work at General Motors Institute and is illustrative of how design classes are integrated with mechanical engineering laboratory work. Data obtained from the laboratory were used in the design class. The concepts developed in the design class were then tested and evaluated in the laboratory.

of their center of gravity from the center of the crankshaft were obtained and tabulated (Fig. 1) it was then possible to proceed with calculating the unbalanced forces and, in turn, balance the engine.

One of the first steps in the solution to this problem, which will appear in the April-May-June 1958 issue of the GENERAL MOTORS ENGINEERING JOURNAL, will be to determine the value of a centrifugal force constant Q due to the reciprocating weight W .

Contributors to Jan.-Feb.-Mar. 1958 Issue of

ENGINEERING



RICHARD P. BARNARD,

contributor of "A Dilemma of Group Research—Determination of 'Inventorship'," is a patent attorney with the General Motors Central Office Patent Section in Detroit. He joined the Patent Sec-

tion in 1948 as a patent searcher in the GM Patent Office in Washington, D.C.

In 1951 Mr. Barnard was promoted to patent attorney and was transferred to the Central Office in Detroit. He returned to Washington, D.C. the following year as assistant manager of the Patent Office there. In 1956 Mr. Barnard returned to Detroit.

Mr. Barnard is currently supervisory attorney for patents concerning automotive fuel systems, including carburetion and fuel injection; cigar lighters; tubing; wheel covers; and external vehicle hardware.

Mr. Barnard received a bachelor of science degree in mechanical engineering from the University of Michigan in 1947, and a bachelor of law degree from George Washington University in 1950. He is a member of the American Bar Association, the American Patent Law Association, the Michigan Bar, and the Bar of the U.S. Supreme Court.



EDWARD K. BENDA,

co-contributor of "Electronic Control System Provides Indoor Proving Grounds for Transmissions," is instrumentation supervisor of Chevrolet Motor Division's Experimental Laboratory, located at

the Chevrolet Engineering Center, Warren, Michigan. In this position he is responsible for the supervision of dynamometer instrument maintenance, tests involving instrumentation techniques, and sound and vibration tests on automotive components.

Mr. Benda joined General Motors in 1952 as a college graduate-in-training with the GM Research Staff. The following year he was promoted to research engineer. While with the Research Staff Mr. Benda worked on projects which included the development of an automatic transmission shift evaluator and the development of a system for the automatic control of turbine blade vibration amplitude in a turbine blade fatigue machine. In 1955, Mr. Benda was transferred to Chevrolet and assumed his present position in 1956.

Mr. Benda was granted a B.S. degree in electrical engineering from Michigan College of Mining and Technology in 1950. His technical affiliations include the Instrument Society of America and the Society of Automotive Engineers. He also is a member of Eta Kappa Nu, honorary society.

STEVE CENKO,

faculty member-in-charge for the typical General Motors Institute laboratory problem "Determine the Center of Gravity Location of a Passenger Car" and the solution appearing in this issue, is head of



the Mechanical Engineering Laboratory Section at G.M.I. He is responsible for developing experimental laboratory problems which are integrated with design classes and which utilize present day laboratory techniques for the solution of engineering problems.

Mr. Cenko joined General Motors in 1944 as a G.M.I. co-op student sponsored

by the Detroit Transmission Division. In 1949, after receiving a B.M.E. degree from G.M.I., he was made a junior engineer at Detroit Transmission and did developmental work on automatic transmissions. The following year he joined the faculty of G.M.I. as head of the transmission section of the Product Service Department. In 1955 he was transferred to the Product Engineering Department and assumed his present position. His teaching experience has been in the fields of internal combustion engines and their accessories and the automobile chassis and chassis units.

Mr. Cenko is a member of the American Society for Engineering Education. He is presently completing work for a master's degree at Wayne State University.

RAYMOND A. GALLANT,

co-contributor of "Electronic Control System Provides Indoor Proving Grounds for Transmissions," is head of Chevrolet Motor Division's Instrumentation and Automotive Electrical Department, located at the Chevrolet Engineering



Center, Warren, Michigan.

Mr. Gallant joined General Motors in 1950 as a college graduate-in-training with the GM Research Staff. In 1954 Mr. Gallant left the Research Staff on an educational leave of absence and spent one year teaching, taking graduate work, and doing research work on ball bearings at Rensselaer Polytechnic Institute. The following year he joined Chevrolet to organize the Instrumentation Department.

Mr. Gallant is responsible for providing proper facilities used for evaluating automotive component performance. He is currently supervising development projects, sound and vibration studies, and experimental stress analysis.

Mr. Gallant received the B.M.E. degree from Rensselaer Polytechnic Institute in 1950 and the M.S. degree in engineering mechanics from the University of Michigan in 1954. He is a member of the Society of Automotive Engineers, American Institute of Electrical Engineers, Instrument Society of America, and the Society for Experimental Stress Analysis. Mr. Gallant is also a member of Tau Beta Pi, Sigma Xi, Pi Tau Sigma, and Alpha Psi Omega, honorary societies.



DR. LAWRENCE R. HAFSTAD,

contributor of "Research as Applied to Traffic Engineering," is vice president of General Motors in charge of the Research Staff. He graduated from the University of Minnesota in 1926 with a B.E.E.

degree and remained there for two more years, when he then joined the Carnegie Institute, Washington, D.C. Dr. Hafstad continued his advanced studies at Johns Hopkins University and was awarded a Ph.D. degree in physics in 1933.

Dr. Hafstad remained on the staff of the Carnegie Institute until 1946. During World War II he also was assigned to the staff of the Applied Physics Laboratory at Johns Hopkins. In 1947 Dr. Hafstad was named executive secretary of the Research and Development Board, Office of the Secretary of Defense. In addition, he also served as professor of applied physics at Johns Hopkins and director of the Johns Hopkins Institute for Cooperative Research.

Dr. Hafstad served as the first director of the U.S. Atomic Energy Commission's Reactor Development Division from 1949 to 1955, being responsible for the developmental programs for nuclear powered submarines and aircraft, as well as civilian atomic power. During this period he also carried a Presidential appointment as chairman of the Interdepartmental Committee on Scientific Research and Development.

In January 1955 Dr. Hafstad became director of the Chase Manhattan Bank's Atomic Energy Division. In September of that year he resigned to join GM as vice president in charge of the Research Staff.

NORMAN D. LAWLESS,

contributor of "Manufacturing Engineers Develop New Method to Statically Balance Speedometer Drag Cups," is a process engineer in the Manufacturing Development Engineering Department of AC Spark Plug Division, Flint, Michigan.



ment of AC Spark Plug Division, Flint, Michigan.

Mr. Lawless joined AC in 1951 as an engineer-in-training after receiving a bachelor of science degree in electrical engineering from Michigan State University. Upon completion of his training program he was promoted to junior process engineer and then to his present position.

Mr. Lawless is presently concerned with the development of special machines and processes for the instrument manufacturing operations of AC Spark Plug. His past projects have included the development of straight line assembly machines for the integrated assembly of ammeters, fuel gages, and component assemblies. Mr. Lawless also has been concerned with the development of special coil winding machines and balancing machines and fixtures.

The technical affiliations of Mr. Lawless include membership on the General Motors Master Mechanics Balancing Committee.



WALTER D. NOON,

co-contributor of the problem "Determine the Operating Characteristics of a Drive and Control System for a Transfer Mechanism," and the solution appearing in this issue, is a senior project engineer

in the Electronics Department, Process Development Section of the General Motors Process Development Staff, located at the GM Technical Center.

Mr. Noon is in charge of the Analysis and Instrumentation Group of the Electronics Department. This Group assists engineers in the application of mathematics, computers, and instrumentation to the analysis and solution of the Staff's engineering problems. These problems arise during the design and development of mechanical, electronic, foundry, hydraulic, and pneumatic systems.

Mr. Noon is a 1951 graduate of the University of Michigan, where he was granted the B.S. degree in physics. He

Contributors' backgrounds vary greatly in detail but each has achieved a technical responsibility in the field in which he writes.

received the M.S. degree in physics from Wayne State University in 1953, where he now teaches evening classes.

Before joining the Process Development Section in 1955 as a project engineer, Mr. Noon was employed as a flight test analysis engineer with Lockheed Aircraft Corporation from 1951 to 1952. He also worked as a senior systems design engineer in electronics with Chance Vought Aircraft Corporation from 1953 until he joined General Motors.



G. J. O'KANE,

contributor of "Planning and Operating an Industrial Waste Disposal Plant for a New Plating Facility," is engineer-in-charge of Process Engineering at Ternstedt Division's Columbus, Ohio, Plant.

Mr. O'Kane graduated from the University of Detroit in 1939 with a bachelor of science degree. Following graduation, he was employed in the fields of metallurgical and chemical testing until he joined Ternstedt in 1943 as a chemist. Mr. O'Kane was promoted to process engineer in 1945, senior process engineer in 1948 and engineer-in-charge of Process Engineering, his present position, in December 1951.

Currently, Mr. O'Kane supervises physical and chemical testing and the waste disposal plant. Some of his previous contributions at Ternstedt were the development of electrostatic spraying for garnish molding and the introduction of single coat garnish molding paint.

Mr. O'Kane is a member of the American Society of Metals and the American Electroplaters Society.

GEORGE W. ONKSEN,

contributor of "Why Cars Have Four Headlights," is Engineering Head, Research and Development for Guide Lamp Division, Anderson, Indiana. His current responsibilities include the development



of automotive exterior lamps and electronic control devices. He assumed his present position in March 1957.

Mr. Onksen joined General Motors in 1928 as an apprentice toolmaker with Delco-Remy Division. He began his college training at Purdue University and after one year transferred to the General Motors Institute as a co-op student under the sponsorship of Guide Lamp Division. In 1933 he was awarded a four-year diploma from G.M.I. and was then assigned to the Engineering Department of Guide Lamp, where he worked on vehicular lighting problems.

In 1936 Mr. Onksen was promoted to supervisor of research and in this capacity worked on the development of Sealed Beam headlamps and automatic controls of headlamps. One result of the research and developmental projects was the Autronic-Eye automatic headlight control unit.

Thirty-two patents in the automotive lighting and related electronics fields have resulted from Mr. Onksen's work. His technical affiliations include membership in the Society of Automotive Engineers. He also is a member of Alpha Tau Iota honorary society.

In 1956 Mr. Onksen was granted a bachelor's degree in industrial engineering from General Motors Institute.

JOHN R. PRIOR,

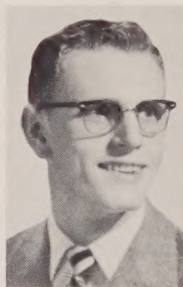
contributor of "Applying the Electrodynamical Vibrator to the Development of Military Vehicles," is a staff engineer at Cadillac Motor Car Division's Cleveland, Ohio, Ordnance Plant. In this

capacity he is in charge of the Power Train and Electrical Department, which is responsible for the design of engine, transmission, final drive, and electrical components of all ordnance vehicles engineered by Cadillac. These components include such items as fuel injection systems, dry-type air cleaners, and alternators for electrical systems.

Mr. Prior joined General Motors in 1949 after graduating from The Ohio State University with a bachelor's degree in mechanical engineering. He was employed originally as a laboratory technician at the GM Proving Ground, Milford Michigan. In 1951 he was transferred to the Cleveland Ordnance Plant as a proj-

ect engineer. The following year he was promoted to senior project engineer and in 1955 was made assistant staff engineer in the Test and Development Department. He assumed his present position in August, 1957. Some of Mr. Prior's previous major projects include developmental work on cross-drive transmissions and simplified turret controls for tanks and studies of air and rolling resistance of automobiles.

Mr. Prior's technical affiliations include the Society of Automotive Engineers, the Coordinating Research Council's Inspection Panel for Power Transmissions, and the GM Engine-Fuel Relationship Sub-Committee. He also is a member of Pi Tau Sigma, honorary society.



GEORGE L. SCHRENK,

co-contributor of "An Analog Method for Finding the Real and Complex Roots of Higher Order Polynomial Equations," was a 1957 summer employee of Allison Division, where he was

assigned special projects involving analog computer techniques.

Mr. Schrenk, a General Motors Scholarship holder, is currently a senior at Indiana University where he is majoring in physics, with minors in mathematics and chemistry. He will complete his work for his bachelor of science degree in physics in February 1958, a total of two and one-half years from his date of entry.

He is a member of Phi Eta Sigma, honorary society.



PHILIP WEST,

co-contributor of the problem "Determine the Operating Characteristics of a Drive and Control System for a Transfer Mechanism," and the solution appearing in this issue, is a senior project engineer

in the Process Development Section of the General Motors Process Development Staff, located at the GM Technical Center.

Mr. West joined GM in 1945 as a General Motors Institute co-op student sponsored by AC Spark Plug Division. He graduated from G.M.I. in 1949 with a bachelor of industrial engineering degree. After receiving his B.I.E. degree he left AC Spark Plug to enter the G.M.I. Dealer Cooperative Training Program. Upon completion of this program he worked for a Buick dealership until 1954, when he joined the Process Development Section as a junior engineer. He was promoted to project engineer in 1956 and assumed his present position in 1957.

Mr. West's work as a senior project engineer, in the Engineering Design Department of the Process Development Section, concerns project studies involving processing analysis and automatic machining and assembly machine development.

The technical affiliations of Mr. West include the American Society of Tool Engineers. He also is a member of Phi Eta Sigma and Alpha Tau Iota, honorary societies.



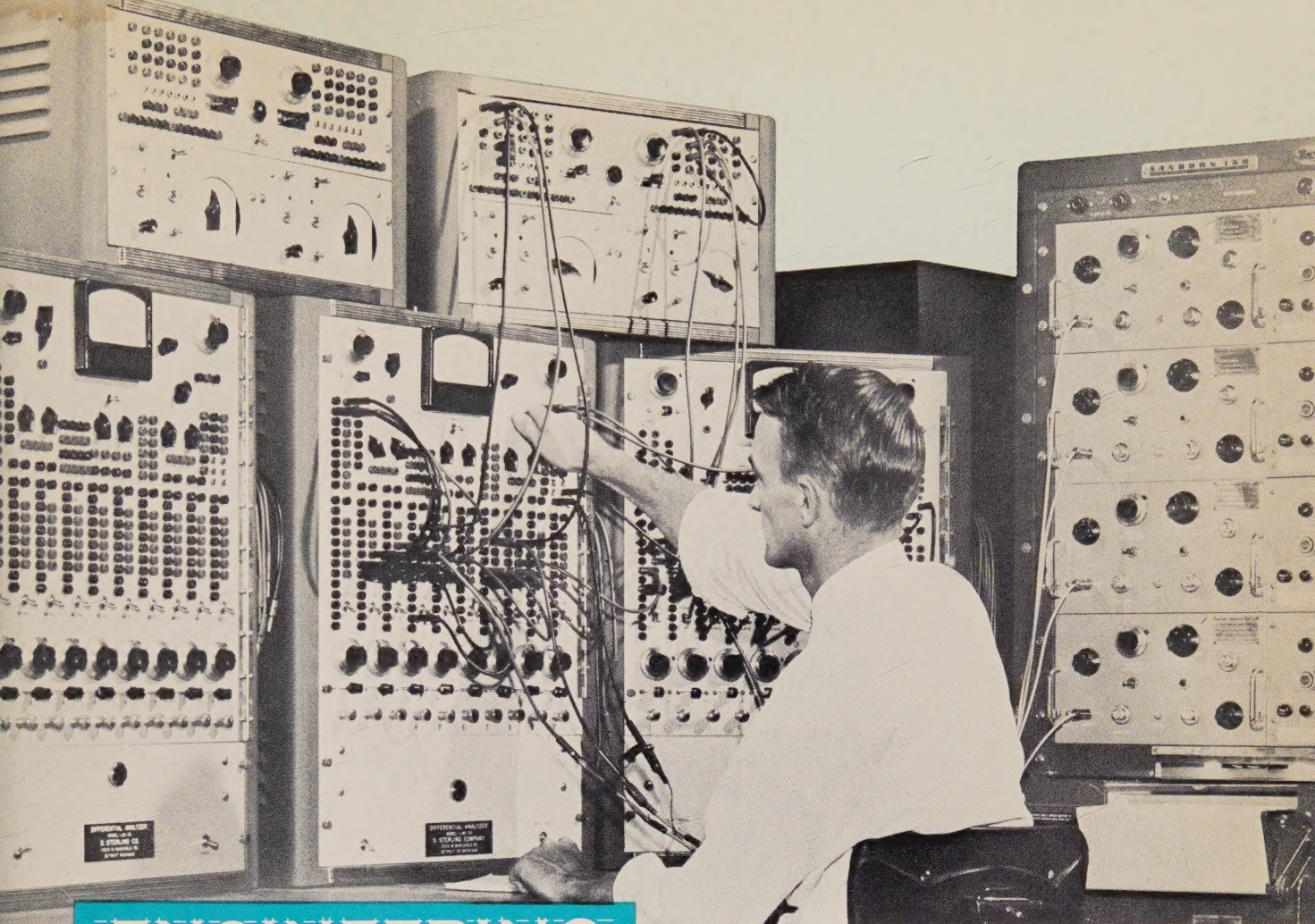
R. O. WHITAKER,

co-contributor of "An Analog Method for Finding the Real and Complex Roots of Higher Order Polynomial Equations," is project engineer in the Analog Computer Group of Allison Division, Indianapolis, Indiana.

Mr. Whitaker joined General Motors in 1955 as an instrumentation engineer with Allison's Electronics and Parts Test Department. Previously, he was engaged in the design of industrial instrumentation.

Mr. Whitaker's current work includes the analysis of special dynamic problems and their preparation for solution by an analog computer. Other assignments have included studies of heat exchangers, control systems for jet engines, the dynamic action of particular engine components, and the performance of electrical networks. One patent has been granted based on his work in the field of remote control.

Mr. Whitaker received a bachelor of science degree from the University of Iowa in 1946. He is an associate member of the Institute of Radio Engineers.



ENGINEERING

ASSIGNMENT IN GM

Many complex engineering problems require a detailed mathematical analysis in the form of equations to provide useful quantitative data for their solution. To complete the analysis, tedious and time consuming computation often is required and, in some cases, the equations developed prove impossible to solve. Until recently, this has made the mathematical analysis more useful as an aid to understanding a complex engineering problem rather than providing a useful numerical solution. The advent of high speed, multi-purpose computers, however, has changed all this and has made it possible to provide quantitative answers to complex engineering problems by means of detailed mathematical analyses.

The analog computer is one of the devices playing an increasingly important role in engineering research and development work. At AC Spark Plug Division this versatile engineering tool is used in the design and development of control systems ranging from the simple mechanical to the complex electro-mechanical-hydraulic. The computer provides a ready means for analyzing dynamic response and establishing design

limits on proposed systems. The analog computer also is used for solving problems in airborne navigation, automotive controls, and laboratory instrumentation.

In the accompanying photograph Robert Gelenius, project engineer at AC Spark Plug, is shown using the analog computer for still another typical application—investigation of a dynamic response problem involved during the shift in a hydraulic transmission. In this case the analog computer was used to show how a smoother shift could be obtained. Major components of the computer are three electronic differential analyzers, shown in the center, on which are mounted servo multipliers. The panel at the right is a four-channel recorder.

Mr. Gelenius joined AC Spark Plug in 1950 after graduating from Michigan State University with a B.S. degree in electrical engineering. In 1951 he was made a detail engineer and assumed his present position in 1953. At the present time, Mr. Gelenius is attending the University of Michigan graduate school taking special work for a Master's degree in instrumentation engineering.



GENERAL MOTORS ENGINEERING JOURNAL

